

**Introduction of Inquiry-based Science Teaching in Rwandan Lower
Secondary Schools: Teachers' attitudes and perceptions**

by

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**A Dissertation submitted in fulfilment of the requirement for the degree of
Doctor of Philosophy in the School of Education**

University of KwaZulu-Natal

Edgewood, December 2012

ABSTRACT

This study describes, discusses and analyses the Rwandan lower secondary school teachers' responses to the introduction of inquiry as a teaching approach in the science curriculum as one of the changes that the curriculum in Rwanda has undergone through in the aftermath of the 1994 genocide. The study investigates the science teachers' understanding of inquiry-based science teaching, their attitudes towards the introduction of inquiry into the science curriculum, the activities they are engaged in with regard to inquiry-based science teaching and learning, the factors influencing their current teaching practices and their perceptions about what may be done for a better implementation of inquiry-based science teaching.

Guided by a pragmatic research approach, I believed that collecting diverse types of data would provide a deeper understanding of the research problem and therefore adopted a two phases' sequential explanatory mixed methods design. During the first phase, data were collected by means of a survey questionnaire administered to a purposeful sample of 200 science teachers at lower secondary school in Rwanda. Findings from the survey informed the second phase consisting of data collection by means of semi-structured one-to-one interviews with 15 purposefully selected teachers from the sample used in the first phase then supplemented by a contextual observation in their schools. The data from the questionnaire were subject to a descriptive statistical analysis while data from interviews were subject to analysis involving transcribing and reading interview transcripts, coding and categorizing information, identifying patterns, and interpreting.

The data analysis produced five main assertions providing answers to the research questions. Participant teachers displayed varying understanding of what inquiry-based science teaching is, associating it with a number of its characteristics such as a learner centred teaching approach mostly based on experiments and practical work. There were a few teachers who did not have accepted understandings of inquiry-teaching. Furthermore, teachers had a positive attitude towards the introduction of inquiry and favoured the change even though they indicated a number of factors preventing them from adequately implementing the new teaching approach. As for their practices, traditional classroom

activities were more frequently used than inquiry-based activities and when they made use of inquiry, they followed a specific order of activities that led to a more structured type of inquiry. The study further identified a number of factors influencing both positively and negatively the implementation of inquiry. The positive aspect was that they find teaching through inquiry more enjoyable while the shortage of time, the lack of teaching resources and the lack of confidence associated with inadequate training, influenced negatively the way they implemented inquiry-based teaching. Teachers highlighted a number of interventions they felt would make the implementation of inquiry based teaching more effective. The improvement of resources provision to schools and the implementation of adequate professional development programmes were the most highlighted. Despite the several impediments to the implementation of effective use of inquiry, teachers were optimistic towards the future of science teaching and learning in Rwanda. It is envisaged these findings will be valuable to a wide range of audiences including science teachers, curriculum developers, science teacher educators as they may inform them about the implementation of the new curricula that require teachers to focus on inquiry given the controversy surrounding this issue in science education.

DECLARATION

I, MUGABO Rugema Leon, declare that:

- (i) The research reported in this thesis, except where otherwise indicated is my original work;
- (ii) This thesis has not been submitted for any degree or examination at any other university;
- (iii) This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;
- (iv) This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
 - a) their words have been re-written but the general information attributed to them has been referenced;
 - b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced.
- (v) The work described in this thesis was carried out in the School of Education, University of KwaZulu-Natal, from 2009 to 2012 under the supervision of Prof. Paul Hobden (Supervisor); and
- (vi) The Ethical clearance No.**HSS/1011/010D** was granted prior to undertaking the fieldwork.

Signed:

As the candidate's Supervisor I, Paul Hobden, agree to the submission of this thesis.

Signed:

ACKNOWLEDGEMENTS

There are as many people as institutions without whom this thesis would not have been produced and to whom I am greatly indebted.

First of all, I would like to thank the Government of Rwanda for its commitment to invest into his people through education and therefore for having provided full scholarship to pursue my studies as well as the University of KwaZulu-Natal that has been my second home for all my postgraduate studies.

It has been a privilege to have Prof. Paul Hobden as supervisor to whom I would like to express my deepest gratitude for his continued encouragement, expertise and academic support that he provided at every stage of the research process.

My sincere thanks and appreciation goes also to Prof. George K. Njoroge, the Rector of Kigali Institute of Education for his advice during the crucial moment of applying to embark on this PhD journey now near the end.

I consider myself fortunate to have support, patience and love of my family especially my children for understanding why daddy had to leave them for these last few years.

My deepest gratitude is extended to all science teachers who willingly accepted to participate in this study and the regional inspectors for their support during my fieldwork.

To my dear friends, flat mates and colleagues, you also deserve a word of thank. I will always remember the language and terms of support we created during those days of hardship.

Finally, my particular thanks are directed to Mr Mpamo Aimé who beyond our many years of struggle for life, has become more than a brother and made sure that my absence did not make any impact to my family. In my absence, I was always secured knowing that you were there in my place. May God give you overflowing blessings!

DEDICATION

I would like lovingly to dedicate this thesis to my wife and children for having understood the reason of leaving them for years to embark on a journey normally perceived as for young persons. This doctoral qualification is in recognition of your support and may always remind you to move confidently in the direction of your dreams.

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LIST OF ABBREVIATIONS

AAAS	American Association for Advancement of Science
BEd	Bachelor of Education
B.Sc.	Bachelor of Science
BTC	Belgium Technical Cooperation
EST	Elementary Science and Technology
GIE	General Inspectorate of Education
IAP	Inter Academy Panel
IBSE	Inquiry-based science education
IBST	Inquiry-based science teaching
ICT	Information and Communication Technology
JICA	Japan International Cooperation Agency
KIE	Kigali Institute of Education
MINEDUC	Ministry of Education (Rwanda)
NCDC	National Curriculum development centre
NCSTI	National Council for Science, Technology and Innovation
NHEC	National Higher Education Council
NRC	National Research Council
NSES	National Science Education Standards
PDP	Professional Development Programme
Qual	Qualitative
QUANT	Quantitative
QTS	Qualified Teacher Status
REB	Rwanda Education Board
RNCU	Rwanda National Commission for UNESCO
RNEC	Rwanda National Examination Council
SFAR	Students Financing Agency for Rwanda
SMASSE	Strengthening Mathematics and Science Secondary Education
TVET	Technical and Vocational Education and Training
TSC	Teacher Service Commission
TTI	Teacher Training Institutions
UNDP	United Nations Development Programme
UNESCO	United Nations for Education, Science and Culture Organization
UNHCR	United Nations High Commission for Refugees
UNICEF	United Nations Children's Emergency Fund
WDA	Work Development Authority

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CHAPTER ONE

INTRODUCTION

This thesis discusses and analyses Rwandan lower secondary school science teachers' responses to the introduction of inquiry as a teaching approach into the science curriculum. Despite my long experience in science education in Rwanda, to my knowledge few studies exist in this area and none of them has specifically focused on teachers' responses to the introduction of inquiry at lower secondary school. This curriculum revision was one of the recent reforms that the science curriculum in Rwanda has undergone in the aftermath of the country's turmoil of 1994.

The study takes place at a time when Rwanda is still facing a problem of shortage of resources both physical and human, as well as inadequate teacher professional development programmes. It also takes place within another context of change in the Rwandan educational system, as it moves towards 9 years of basic education and a shift from French to English as medium of instruction.

This chapter introduces the thesis. It provides the background to the study, the rationale of the study and research questions that guided the study. It also presents in brief the methodology approach adopted, explains the significance of the study, and gives an overview of the thesis.

1.1. BACKGROUND TO THE STUDY

Following the 1994 genocide in Rwanda, with its side-effects on all sectors of the country's life including education, a range of school reforms have been implemented. In science education particularly the call for reform has been strong, because science was seen as a core driver of the socio-economic development of the country. The most recent reform in science education partially motivated the need for carrying out this study. It dates from 2006 with the revision of the science curriculum at lower secondary school, introducing among other aspects an inquiry-based teaching approach. Its implementation started in 2007, but not

much was done in terms of teachers' preparedness for this change that was introduced. In nearly all instances teachers find themselves under strain as being most responsible for implementing the change, which requires to some extent a shift in belief and practices. In this case, where the change in question was the introduction of inquiry into the science curriculum, it may even be more complex since it is well documented that many pre-service teachers do not employ inquiry instructional practices upon leaving their preparation programmes (Brown & Melear, 2005).

For more clarification about the context in which the study is conducted, it is important briefly to explain to the reader how the education system in Rwanda operates. The education sector in Rwanda consists of policy makers, administrators, teachers, students and school administrators who all contribute to the task of ensuring that educational goals are achieved. The educational system in Rwanda is under the responsibility of the Ministry of Education (MINEDUC), which sets policies, norms and standards for the education sector and undertakes planning, monitoring as well as evaluation at national level (MINEDUC, 2010). Schools are grouped into three categories based on school status: (a) public schools that are fully managed by the government through MINEDUC; (b) private schools owned by non-government proprietors such as individuals, associations or some faith-based organizations; and (c) schools that receive a State grant, also called subsidized, mainly owned by faith-based organizations. Most schools in this last category are owned by the Roman Catholic Church, while a few belong to the Protestant church and the Rwanda Muslim organization.

Although the government oversees the whole educational system through a partnership with all these stakeholders, its role in the daily running of private schools is limited. While the government through the MINEDUC is in charge of designing the curricula, setting the standards and organizing examinations, monitoring teaching and learning and administration, it only pays teachers' salaries and provides teaching resources to public and State subsidized schools. Proprietors of private schools are fully in charge of the day-to-day running of their schools. Regarding the school management and staff appointments like the Head and Deputy Head of the schools, subsidized schools' proprietors propose candidates to the MINEDUC for appointment. However, private school owners

appoint all staff members of their schools themselves under caution of meeting the required profile of the prospective candidate for a particular position.

The MINEDUC has semi-autonomous agencies that operate as public institutions affiliated to the MINEDUC, but with administrative and financial autonomy. These include the Rwanda Education Board (REB), National Higher Education Council, National Council for Science, Technology and Innovation, Work Development Authority, Rwandan National Commission for UNESCO, Institute of Scientific and Technological Research and higher learning institutions, each with a particular mandate to implement specific education policies designed at ministry level (MINEDUC, 2010).

The REB was established guided by the need to improve the quality of service delivery, with the aim of providing quality education by bringing together the main pre-existing implementation bodies, such as the National Curriculum Development Centre (NCDC), General Inspectorate of Education (GIE), Rwanda National Examination Council (RNEC), Student Financing Agency for Rwanda (SFAR) and Teacher Service Commission (TSC) (MINEDUC, 2010). The merging process started around the end of 2009 and was approved by Cabinet in July 2011, and the management teams together with structures of the board were put in place. As a result of this merger the pre-existing bodies were assigned other responsibilities and new names:

1. The former responsibilities of the NCDC were taken over by the REB's curricula and pedagogical materials development, production and distribution for all levels except Technical and Vocational Education and Training (TVET) and higher education.
2. Education inspection, with responsibility for setting and monitoring educational standards at all levels except TVET and higher education, took over the responsibilities of the GIE.
3. Examinations and accreditation became responsible for national examinations at all levels of education (except TVET and higher education), taking over the responsibilities of the RNEC.
4. Teacher development and management took over the former responsibilities of the TSC, including programmes aimed at improving the welfare of teachers at all levels (except TVET and higher education) and establishing conditions of service and guiding appointments, career development, evaluation, promotion and transfer of teachers.

5. Higher education student financing, responsible for modalities of selecting students receiving loans for higher education, took over the responsibilities of the SFAR.

Schooling in Rwanda is made up of four levels of education, namely: (a) pre-school, (b) primary, (c) secondary, and (d) tertiary education, as represented in Figure 2.1.

	Educational level	General primary and secondary	TVET	Teacher Education	General Higher Education
Post-Basic Education	Postgraduate			Postgraduate certificate qualifying to teach in higher education	Postgraduate (Masters and above)
	A0			Degree with Qualified Teacher Status (QTS) for upper secondary	Degree
	A1		College of Technology diploma TVET Grade 1	Diploma with QTS for lower secondary	
	A2 (3 years)	A-level Certificate (S4-S6)	TVET Grade 2; A2	Certificate qualifying to teach in primary school	
Basic Education	Lower secondary (3 years: S1-S3)	O-level Certificate (S1-S3)	TVET Grade 3		
	Primary (6 years: P1-P6)	Primary Leaving Certificate			
	Pre-primary (PS1-PS3)	-			

Figure 2. 1. Rwanda education system: levels and qualifications (Source: MINEDUC, 2010)

Prior to the recent reform that increased the basic education from 6 to 9 years, the above second and third levels were made up of 6 years of primary and basic education and 6 years of secondary school, with the first 3 years corresponding to Grades 7, 8 and 9 constituting ‘lower secondary school’, also called ‘Ordinary level (O level)’ or ‘*Tronc commun*’ as opposed to the ‘upper secondary level’, also called ‘Advanced level (A level)’.

corresponding to Grades 10, 11 and 12. Thus, the 9 years of basic education include both primary school and lower secondary school.

As a result of this change, the first high drop-out of learners could occur only after 9 years of schooling instead of 6 years as it was before. This earlier previous drop-out was due to the fact that at the end of primary school learners had to pass a national competitive examination, from which they were selected to enter secondary school. This selection was restricted by the limited number of places available at secondary school, and this national competitive examination for many years constituted a severe bottleneck in the system for learners, leading to an exceptionally high drop-out rate after primary school.

1.2. MOTIVATION FOR AND RATIONALE OF THE STUDY

My personal interest in science education is a result of having been a science teacher for about two decades in many central African countries including Rwanda following my undergraduate training. I have therefore witnessed first-hand changes occurring in the curriculum as well as teachers' experiences in striving to fit in with those changes, whether or not they were involved in the process of change. Having experienced those changes and more, particularly the most recent that introduced inquiry into the lower secondary school science curriculum, I felt that it was important to investigate how teachers responded to this change. With no shadow of a doubt, the successful implementation of any change in the curriculum depends on the teachers' acceptance and receptivity, as well as their capabilities.

As pointed out by Earnest and Treagust (2001), science and technology education leads to a scientifically and technically literate labour force. Such skilled personnel enable economic progress in countries lower down the development ladder: "improving science education is often regarded as a priority for developing countries in order to promote long-term economic development" (Rogan & Grayson, 2003, p.1171). Rwanda is among these developing countries that, despite their budget constraints, try to invest heavily in science education to strive for socio-economic development. Subsequently Rwanda has adopted, among other educational goals, national capacity building in science and technology and improvement in the teaching of science at all levels (MINEDUC, 1998a). The country is

committed to using science, technology and education to drive economic growth and development of the nation's human capital. This Rwandan effort is being witnessed worldwide. For example, in a recent visit to Rwanda of high-level American Association for the Advancement of Science (AAAS) officials, they acknowledged that they were impressed by Rwanda's effort to recover from its 1994 genocide by using science and technology to improve the economy, education and lives of its people (AAAS, 2008).

At each and every level of the educational system efforts are being made to achieve these goals. At primary level pupils are taught to observe the environment which surrounds them and encouraged to learn by handling different objects, while before the focus was on learning the content of science. This was made concrete through introduction into the curriculum of a course entitled 'Elementary Science and Technology (EST)', taught in all grades of primary school. Although the course is learner-centred, with much emphasis on inquiry, there is still a lack of required teaching resources as well as well-prepared teachers to deal with such a teaching approach. At secondary level science is taught through three separate subjects, namely biology, chemistry and physics. At both lower and upper secondary levels there is a shortage of laboratory materials and equipment for these subjects as well as a lack of adequately qualified teachers. Added to this, there are some schools that have equipped laboratories, whether supplied by the government or donated by aid organizations but that are often underutilized.

However, at lower secondary level - which is the focus of this study - considerable efforts have been made aimed at improving the quality of science teaching and learning, although much still needs to be done. After the revision of the science curriculum emphasizing the inquiry-based teaching and learning approach, teachers were trained and basic manuals produced and distributed to all schools that host the lower secondary level. By the end of 2008 a study on implementation of the revised science curriculum and the impact of the related science teachers' training was conducted, in which I was personally involved. The resultant report highlighted the poor science teaching conditions, pointing out the lack of adapted teaching materials, manuals and textbooks, the shortage of well-trained teachers and the high rate of teachers' mobility, with them leaving teaching for other jobs (MINEDUC, 2008c). However, it was found that the revised curriculum was widely welcomed by teachers, who were hoping that more accompanying measures such as in-service trainings, supply of

textbooks and other teaching aids were to be provided along with it. This earlier evaluation took place after only one year of implementation of the new curriculum. Therefore I felt that it was worth to undertake this study at this time as it would shed light on the way teachers embrace and implement the change abandoning traditional approaches to teach science in favour of more constructive and inquiry-based approaches. Such study would assist in considering appropriate measures to accompany the change in the beginning and avoid adjustment at a later stage.

1.3. SPECIFIC RESEARCH QUESTIONS

Using Bassey's (1999) metaphor in the field of research, a research question is compared to the engine which drives a train of inquiry, and should be therefore formulated in such a way that it sets the immediate agenda for the research. Even though, it is obviously expected that the research questions could be modified and replaced as the research goes on, "without them the journey will be slow or chaotic" (p. 67).

This study was designed to explore the responses of Rwandan lower secondary science teachers to the introduction of an inquiry-based teaching approach in the curriculum. More specifically, the study investigated the teachers' understanding of inquiry-based science teaching, their attitudes towards the introduction of inquiry into the science curriculum, the activities they are engaged in the science classroom with regard to inquiry-based science teaching and learning, the factors influencing their current practices, and their suggestions for better implementation of the inquiry-based science teaching. These five issues of interest guided the research activities and were translated into the following specific research questions:

1. What is Rwandan O-level science teachers' understanding of inquiry-based science teaching?
2. What attitudes do Rwandan O-level science teachers have towards the introduction of inquiry-based science teaching into curriculum?
3. What classroom activities do these teachers engage in with regard to inquiry-based science teaching?
4. Why do these teachers respond to inquiry-based science teaching in the way they do?

5. Based on their current practices, how do they think inquiry-based science teaching could be more effectively implemented?

This study was carried out guided by a pragmatic research paradigm I opted for the use of mixed-methods research with a sequential explanatory design involving a two-phase data collection using both a survey questionnaire and interviews as this suited my research purpose. I believed that collecting diverse types of data would provide a deeper understanding of the research problem. Findings from the data collected during the first phase by means of a survey questionnaire informed the second phase, consisting of in-depth semi-structured interviews supplemented by contextual classroom observation. The rationale of mixing both kinds of data was grounded in the researcher's conviction that "neither quantitative nor qualitative methods are sufficient by themselves to capture the trends and details of a situation" (Ivankova, Creswell & Stick, 2006, p. 3). Details about the research design and associated activities are presented in Chapter Four.

1.4. SIGNIFICANCE AND CONTRIBUTION OF THE STUDY

Inquiry-based science education (IBSE) has been implemented in both developed (such as Australia, France, the United Kingdom and United States of America) and developing countries (sub-Saharan African countries including South Africa), with contrasting experiences and different variants. However, as yet little is known about IBSE in developing countries (Harlen & Allende, 2010).

As stated before, very few studies exist that examine the Rwanda educational system in general and science education in particular. None of them focused on the lower secondary school with regard to the changes to the curriculum over the years. This study pioneered the use of research techniques to examine the teachers' experiences and attitudes towards inquiry-based science teaching and its implementation as emphasized in the new science curriculum. This new teaching approach is within an environment strongly affected by both a lack of resources and poor teacher professional development programmes. Moreover, an unprecedented increase in the number of learners entering lower secondary school as a result of the fast-tracking nine-year basic education which began in 2009 has further significantly changed the existing structures of lower secondary school in Rwanda (MINEDUC, 2010).

This research provides information on the current status of science education in Rwanda. More particularly, it highlights constraints to the implementation of inquiry-based science teaching at lower secondary school level. It may assist in developing strategies for renewed professional development to promote effective implementation of inquiry-based science teaching and learning. The study may also enlighten educational managers, such as those responsible for curricula, inspection of education, examination and accreditation, teacher development and management as well as all other stakeholders in their various interventions aimed at improving the quality of education in general and science in particular.

The study also identifies the needs of and key issues faced by teachers striving with a dilemma between the intended and implemented curriculum. By informing authorities about the prevailing science teaching environment from the viewpoint of the teachers themselves, the findings may be used to review teacher education programmes in both pre-service and in-service towards creating ones more relevant for the needs of today's society and that enable bridging of the gap between the intended and implemented science curricula.

From the above considerations, the study seems to have three levels of significance. The first level of significance is in terms of science teachers' involvement in the study. The research provides teachers with the opportunity to express themselves and reflect on their significant role in implementation of the changes brought into the curriculum. This may help teachers to better understand the constraints they face in implementing inquiry-based science teaching and ways of circumventing them.

The second level of significance is for those who have responsibility in education management and more specifically those in charge of curriculum initiatives. Since the research is designed to describe the prevailing relationship between the intended and implemented science curriculum, recommendations to classroom curriculum implementers who are teachers might allow both parties to overcome constraints they face in Rwanda.

The third level of significance is for the researcher who is also a science teacher educator. From my personal experience through observing teachers in the classroom, visiting schools especially during school practice, I was able to notice difficulties in implementing the new curriculum and therefore the teaching approach. Despite the wide promotion of inquiry-based science, the reality in many countries (including Rwanda) is that most of the support

materials available to teachers, such as curriculum materials, school textbooks and experiment guidelines, still mainly offer non-inquiry experiments, activities and exercises. Consequently there is a need for teachers to consider other teaching approaches rather than trying to convert the existing lesson material into the more open inquiry-based one.

Over and above these three levels of significance, the need for undertaking such a study was obvious since the research envisages extending the knowledge base with regard to inquiry-based science teaching (IBST) in Rwanda. Furthermore, the study is expected to provide valuable guidance both to Rwandan and South African teachers in how to implement the new curricula, which both require science teachers to focus on inquiry, given the controversy surrounding this issue in science education.

1.5. STRUCTURE OF THE THESIS

The design, development and findings of this study are presented in seven chapters. The present chapter is the general introduction to the study. It provides the background of the study, the motivation for and rationale of the study, the formulation of specific research questions and the significance and contribution of the study. It ends by presenting the structure of the thesis, which is a brief content description of each chapter.

Chapter Two talks about science education in Rwanda. Issues including the evolution of science education in Rwanda, the science curriculum in Rwanda and science teacher education in Rwanda are discussed in this chapter. Chapter Three reviews the literature pertinent to the present study and links it with the theoretical framework. Issues including the constructivist theory of learning, inquiry science teaching and learning and the teachers' changes with curriculum reform are discussed in this chapter. The research activities are outlined in Chapter Four, which contains the research design and methodology, with a description of the population and participants, data collection strategies and process. Issues including validity, reliability and ethical considerations are discussed in this chapter.

Chapter Five and Chapter Six are about the research findings, which were first presented in one chapter that became disproportionately big and was later divided into two.

One deals with teachers' understanding and attitudes towards IBST and the second is about teachers' practices, factors influencing those practices and suggested ways of better implementation of IBST. In these two chapters data are analysed and findings presented and discussed. Finally, Chapter Seven provides the implications of the study, the conclusion and recommendations. This last chapter also provides some limitations of the study as well as suggestions for future research directions.

CHAPTER TWO

SCIENCE EDUCATION IN RWANDA

This chapter aims to describe and discuss the situation of science education in Rwanda, from the period prior to introduction of today's formal schooling to date. Because the study takes place at the University of KwaZulu-Natal in Durban, South Africa, but with reference to another country, I felt that it would be worth including this chapter in the thesis in order to enable readers to understand the general context which the study refers to and how science is perceived within today's education system in Rwanda. It is seen in the context of Africa, because like so many other African countries, education shares the legacy of colonization. In fact, since their independence in the 1960s, most African states have become acutely aware of the importance of science education as a means to scientific and technological development. However in the case of Rwanda, science education has evolved together with the whole education system - hampered by the repeated historical turmoil that characterized Rwandan society and culminated in the 1994 genocide. Science education in Rwanda is therefore discussed with particular reference to the main historical moments that marked Rwandan society, namely the period before, during and after colonization as well as after 1994, each having its own specificities.

This chapter focuses on three sections, namely: (a) the historical evolution of science education in Rwanda, (b) the science curriculum in Rwanda, and (c) science teacher education in Rwanda.

2.1. HISTORICAL EVOLUTION OF SCIENCE EDUCATION IN RWANDA

As indicated in the above introductory paragraph, science education in Rwanda cannot be discussed in isolation from the whole education system. The teaching and learning of science in Rwanda is very recent compared to many other countries worldwide. Any attempt at understanding today's practices may require one to look closely at its evolution through Rwandan recent history. Not only science, but the whole education system in

Rwanda dates only from the last century, compared to other nations which developed science many centuries ago. This situation is a common reality in almost all developing countries.

2.1.1. Education before colonization (before 1900)

It cannot be said that there was no education in Rwanda before 1900, even though there were no schools as we know them today. Before colonization education in Rwanda was informal and delivered largely in the family and community. Knowledge transfer was done through interactions between older and young persons via activities such as storytelling, songs, poetry and dance. Such training was delivered through “*amatorero*” a sort of traditional training school. The courses included military and war skills, iron smithing and foundry work, as well as values such as bravery, a sense of honour, authority and hard labour. Boys practiced hunting or tending the herd and sport with adults while girls stayed at home indoors with their mothers for domestic duties and childminding. During such training sessions the youth were also initiated into traditional rites and religious customs. The traditional school extended from the village to the Royal Court. What was considered as science was traditional or indigenous technology such as handcrafting, smithing and food-related processes as well as the indigenous-based healing of some diseases.

2.1.2. Education during colonization (1900-1960)

The missionaries were the first to introduce the formal education system in Rwanda, in close collaboration with the colonial administration. The first schools aimed at training natives who would then help colonists in their administrative duties and in exploitation of the country’s natural resources. However, from the missionary perspective the objective was to evangelize and train auxiliary administrative staff to serve colonists and facilitate communication with the local communities. In the early 1900s the *Société des Missionnaires d’Afrique* or Missionaries’ Society for Africa commonly known as the ‘White Fathers’, started teaching catechism to Rwandans. They simultaneously founded a number of missions such as Zaza and Nyundo in 1902, Rwaza and Mibirizi in 1903 and Kabgayi in 1906, mobilizing the local people to evangelize them. In addition, the local population was taught

how to read and write in these catechist schools, which can be considered as the first schools to be introduced in Rwanda (Rwanda Education Gateway, 2010).

In 1906 a convention on the organization of schools in Rwanda was signed between the Holy See and the Colonial Government, specifying among other issues the way in which the missionaries would participate in the education of indigenous people. The heritage from this convention still prevails to some extent for some schools under the administration of some faith-based organizations (mainly the Roman Catholic Church). According to the convention the missions were supposed to provide and implement education programmes, whereas the government provided subsidies (Rwanda Education Gateway, 2010).

In 1922, on the initiative of the then Belgian Minister in charge of colonies, Mr Louis Franck, a commission of inquiry was set up to evaluate the administration and organization of education in Rwanda. As a result of the commission a convention known as the 'Jonghe Convention' between the Catholic Church and the Colonial Government was signed in 1925 and introduced the system of free subsidized schools in Rwanda.

About 10 years after 388 primary schools were established and only one secondary school, the prestigious Astrida Secondary School today known as *Groupe Scolaire Officiel de Butare* (GSOB). Graduates were destined to work in administration alongside the colonists. In 1936 some seminaries opened, teaching religion, philosophy and languages. No science was yet being taught.

Around the 1950s a few secondary schools were created for training teachers and nurses, with some of them teaching domestic science, aimed at preparing girls for their future roles as mothers and wives. This may have resulted in disparities between boys and girls in accessing education as well as in entering various scientific fields. Several other catholic subsidized schools were established at this time, to cite but a few: Nyanza Secondary School, Byumba Secondary School and Byimana School of Sciences in 1952, GSNDL de Byimana and Save Secondary School in 1955, and Kansi Nutrition and Home Economics School and Nyanza Christ King's College in 1957. During this time there were some science- related subjects and activities but not yet even a single school or mainstream science teacher training for primary and secondary schools. Also, these few schools of science were for a handful of students, exclusively boys.

2.1.3. Education during post-colonial period (1960-1994)

After colonization many schools remained under the missionaries' responsibility, even though there was a sort of nationalization of schools resulting in increasing the power and control of public schools by government authorities at the expense of the clergy. Access to secondary school and university was still the privilege of very few select Roman Catholic followers and individuals from the ruling classes. Regarding science education, politicians of the time put much emphasis on human and social sciences rather than on natural science disciplines, leading to a very small enrolment in science mainstreams. This may explain to some extent the later shortage of qualified science staff.

Iyamuremye (1966) makes a point about changes and reforms that took place in the Rwanda education system during the years that followed the country's accession to independence. According to Iyamuremye, after independence science education did not significantly improve, but later, as the educational system was maturing, a plan of updating the teaching of science and technology was set up. In 1964, only after one year from the creation of the first national university (the National University of Rwanda), the Rwandan authorities decided to adhere to the Addis Ababa recommendations concerning the restructuring of secondary education, aiming at developing science education. Under the auspices of UNESCO, Ministers of Education from African countries met in Addis Ababa from 15 to 25 May 1961 around the main theme of improving education, considered as the key factor for sustainable development, setting up goals for the period 1961-1980.

The law of 26 August 1966 concerning the restructuring of secondary schools adopted two levels of secondary schooling of three years each, namely lower and upper secondary school. This subdivision remains until today, but has undergone a number of reforms. The goal was the reinforcement of science subjects, aiming at providing learners with a strong grounding in science for upper secondary school.

The then science curriculum of lower secondary school introduced learners to basic knowledge in biology, chemistry and physics as well as mathematics. At upper secondary school science subjects and mathematics were the major subjects in science mainstreams, also called scientific sections. As part of these changes, learners were also familiarized with elementary science and technology notions from primary school.

With time the education system has undergone many reforms aimed at attempting to match the curriculum with the needs of the country, even though they were later criticized for negatively impacting on the expected quality of education. The most famous reforms were those called ‘the 1979 reform’ and ‘the 1981 reform’, which were said to have two main goals, namely the democratization of education and linking school to the process of production and national development as well as reinforcement of national culture (Obura, 2003). With these two reforms, to list but a few of the changes, primary school was extended from six to eight years with much emphasis on the mother tongue, Kinyarwanda, as a medium of instruction, and the abolition of lower secondary school with streams or sections starting from the first year of secondary school.

As stated earlier, these reforms did not bring any satisfactory results with regard to the development of science education. They were severely criticized, which led the government to consider a readjustment, which was effected in 1991. Primary schooling was brought back to six years and emphasis was put on practical teaching at this level through development of a curriculum that aimed at better understanding natural phenomena and preparing learners for secondary school. In a workshop that took place in September 1991, the curriculum developers were tasked to develop a new curriculum. Here attempts were made to incorporate in the curriculum themes related to the environment, from the workshop of March 1992, and the former ‘Initiation into Elementary Technology’ (*Initiation à la Technologie Élémentaire*) changed in name to ‘Elementary Science and Technology’ (EST) (*Science et Technologie Élémentaire (STE)*), which was more encompassing. However, it was only from the 1988/1989 academic year that the EST course was actually effectively introduced in the Rwanda primary school curriculum, with two general objectives describing the primary school graduates’ profile:

1. to acquire methods suited to scientific (to observe, analyze, experiment, represent) and technological (to make, transform, conserve) approaches; and
2. to make learners aware of physical, ecological, economical and socio-cultural phenomena that relate to their lives and to bring them to react to these phenomena in an appropriate way (MINEDUC, 2007b).

It is upon this scientific basis that science education at secondary as well as at tertiary level is rooted.

2.1.4. Science education after 1994

The 1994 genocide in Rwanda left the country totally devastated and the education system collapsed. In the aftermath of the genocide the country's priority was ensuring recovery, rehabilitation and reconciliation, and education was expected to play an important role with regard to this crucial task. Subsequently Rwanda adopted national goals including eradication of illiteracy, universal primary education, teacher training, national building in science and technology, and improving the teaching of mathematics and sciences (MINEDUC, 1998a). However, this endeavour was not without difficulties, because there was an alarming shortage of teachers in general and particularly of teachers in the sciences.

It was and still is a challenge to take into account the realities in the classrooms: the acute lack of material resources and motivation of the very few teachers who were in place. During 1994 and 1998 a 'Teacher Emergency Package' was tried with the help of some United Nations agencies (such as UNHCR, UNDP and UNICEF), and contributed to reopening schools and establishing school routine (MINEDUC, 1998a). This was implemented in two phases: (a) rebuilding the almost non-existent infrastructure in order to reopen schools and start reintegrating teachers and students, and (b) normalizing the education system and reconstituting the infrastructure of educational administration at central and provincial levels (Earnest, 2003).

In 1998, four years after the genocide, a new curriculum was implemented in both primary and secondary schools, in the same context of lack of both human and material resources. The then curriculum was extended to all school subjects. As evidenced by Sinclair (2001), the emergency education themes were related to science and could initiate reflection on peace and reconciliation, and extreme situations that the population was facing such as health and sanitation, water and degradation of the environment were issues incorporated into the implemented curriculum. However, they only became an integral part of the intended curriculum after the 2006 revision. At the same time, the major achievement aimed at producing qualified teachers, including science teachers, was the establishment of the Kigali Institute of Education (KIE). This started with a dire insufficiency of Rwandan educators to impart science education to student teachers, and relied on foreign teaching staff, mostly from neighbouring countries and with some from as far away as India.

With MINEDUC's efforts with the help of various partners, a five-year policy document, a result of the process of implementing the plan of action and strategies set up during the emergency phase, was produced in the same year 1998. However, the Ministry was still working with inadequate human and material resources, which greatly affected the quality of the curriculum delivered, especially the science curriculum (MINEDUC, 1998b). I personally witnessed and experienced this situation when I was a secondary school principal during that period (1995-1998).

In 2003 the education sector-based policy was set with, among other goals, to promote science and technology with particular emphasis on information and communication technology (ICT), as highlighted through the Education Strategic Plan (2003-2008), with sciences and ICT at its core. This plan was articulated around five main points (p. 8):

1. To create at upper secondary level streams specialized in the teaching of ICT and other science subjects as well as technology;
2. To increase science and technology subjects and ICTs;
3. To pay particular attention to science equipment at secondary school;
4. To make all laboratories functional and;
5. To train more science teachers.

At present, although much still has to be done with regard to improvement of the quality of science education, some tangible results are becoming reality and much is expected. For example, the enrolment rate of students in the science mainstreams has increased remarkably during the last few years. In the Mathematics-Physics stream the number of students increased from 164 in 2001 to 11 729 in 2007 (an increase of 7152%), while in the Biology-Chemistry stream the number increased from 293 to 15 966 (an increase of 5449%) for the same period. However, from 2000 to 2007 the teacher qualification rate at secondary school only increased from 43% to 53.4% (MINEDUC, 2008b).

To conclude this section, it can be noted that science education in Rwanda did not earn greater consideration until very recently, when the current leaders of Rwanda acknowledged national capacity building in science and improving the teaching of sciences as a national goal (MINEDUC, 1998a). As one of the most important areas of the curriculum,

science education is still an essential vehicle to provide human resource development, modernization and overall development of countries (Gödek, 2009), and therefore Rwanda seems to be on the right path towards this, despite numerous constraints that the country is still facing.

2.2. THE NEW O-LEVEL SCIENCE CURRICULUM IN RWANDA

Over the last few decades, in many developing countries around the world including Rwanda, the development of curriculum frameworks has been documented as a recent trend in curriculum reform (Earnest, 2003). Rwanda decided to build a knowledge-based economy, with particular emphasis on science and technology as an engine of development, by reviewing the programmes and teaching methods in order to equip the population with knowledge, skills and attitudes for development. The new science curriculum at O level was based on the then existing one, which was criticized for not being quite suitable for students in the first three years of secondary school, with specific objectives putting too much emphasis on contents and too little on methodology. Along with the curriculum revision at ordinary or lower secondary school level, teaching is in response to the principal aim of raising the educational level of the citizens in order to increase capability to participate in the values of culture, civilization and communal life, and to contribute to the development of those values. To make sciences more appealing, this revision of the science curriculum for the ordinary level gives priority to a methodological approach that is student-centred, with particular emphasis on inquiry-related learning situations, enabling achievement of educational objectives and systematic treatment of contents through learning/teaching activities (MINEDUC, 2007b).

Unlike before, this new curriculum takes into account the adaptation of contents to be taught to the age of learners and their previous knowledge, as well as the specific requirements and aims of each subject within the broader scope of the general educational plan. It suggests a methodological approach that gives teacher autonomy in his/her teaching. Despite this autonomy, it clearly defines objectives and material to be taught and proposes flexible learning situations. All three subjects contribute to promoting the students' knowledge, skills and attitudes, offer solutions to problems, and require the student to give

verifiable results. They therefore require that conceptual organization and verification of what was learnt be consolidated by correct use of appropriate terminology.

Certain methodological tools such as individual research, investigation and group work must be seen in this perspective. Therefore, at this level research (preferably to be carried out in class) was to be based primarily on adherence to certain points that are particularly useful for learning, including:

1. the definition of the hypothesis to be verified by experiment;
2. the objective to be attained; and
3. the method chosen and tools to be used.

A correct methodological process would continuously approach the material to be taught in a practical, gradual and consistent manner, with particular emphasis on promoting IBST and learning. Also, the teaching would aim at making the students understand and use subject-specific terminology (MINEDUC, 2007b).

For implementing this revised curriculum, certain modalities were considered. The outline for this curriculum was adopted on the understanding that a detailed teachers' guide would be made available for each of the three science subjects of the curriculum (Biology, Chemistry and Physics) in order to facilitate teaching and learning. This guide suggests to the teacher, among other things, the specific components of each subject curriculum and methods as well as didactic strategies considered most appropriate for the teaching and learning of the subject. It was also expected that implementation of the revised curriculum would require various laboratory materials and equipment together with qualified science teachers, which in turn can only be achieved by means of adequate initial training and regular refresher courses.

In this regard, Rwanda's efforts to improve the teaching of science have been boosted by the supply of science kits to over than 2000 schools through a partnership between the Rwandan Government and the Belgian Technical Cooperation. The science kit is a movable set of science laboratory equipment which can be used as an alternative in schools without a proper laboratory. Over 2000 science teachers have been trained on the use of the science kit, and 1300 of them have been trained on use of the new curriculum and some audio-visual material, and two years later feedback shows a positive impact (MINEDUC, 2010).

The structure of the current science curriculum presents general orientations, general objectives for each subject at O level and approaches for evaluation as well as a detailed programme for each year of study. For every topic under each subject and year of study, the time allocation, teaching aids and one or more learning situations have been suggested as a guide, leaving teachers the freedom to make use of their creativity and initiative with regard to their respective school environment. The curriculum is broken down into its details according to the three columns in Table 2.1, as follows (MINEDUC, 2007b):

Table 2. 1. Structure of the new O-level science curriculum

Specific objectives drawn up in terms of skills or know-how and attitudes	Contents or what is to be learnt	Suggestion of teaching-learning activities (experiments/ practical/ investigation/demonstrations, etc. to be carried out by learners under the teacher's guidance in order to reinforce learning)
-		
-		
Etc...		

Source: MINEDUC (2007b)

Despite the abovementioned measures put in place to implement the new curriculum, it is acknowledged that Rwanda, like many other developing countries, is still struggling with bridging the gap between the intended and the implemented curricula. The commitment to curriculum modernization and teaching has not yet been fully translated into practice. In fact, the reality in most schools continues to be use of didactic methods in large classes with little variety in instructional materials by teachers who have not been exposed for sufficient time to the teaching methods required to implement inquiry in classrooms.

2.3. SCIENCE TEACHER EDUCATION IN RWANDA

According to the 2007 Teacher Development and Management policy, Rwanda, like many other developing countries in Africa, faces the challenging and pressing duty of eradicating poverty. Among other actions envisaged by Rwanda is expanding access to

education without compromising quality, at the same time acknowledging that the teacher is the main instrument for bringing about the desired improvement.

The current qualification framework concerning the teaching profession stipulates that to become a lower secondary teacher a person must gain entry into a national college of education after successfully completing upper secondary schooling, and undertake a 2-year training including teaching practice. For upper secondary school it requires the completion of 6 years of secondary school and a 4-year programme in university, including teaching practice. This also applies to science teachers. However, this is recent because the only institution of secondary teacher training is the KIE, which was established in 1998 and was fully operational in 1999. Today the institution has made a tremendous impact by providing qualified teachers in schools countrywide, even though the recently recorded increase in secondary school enrolment following implementation of the nine years of basic education programme resulted in a corresponding need for more teachers at lower secondary school in general and science teachers in particular.

Information from the prospectus of 2009 indicates that teaching at KIE is organized into three faculties, one of them being the Faculty of Sciences made up of three Departments, namely: (a) the Department of Biology-Chemistry-Physical Education and Sport; (b) the Department of Computer Science, and (c) the Department of Mathematics-Physics, the aim of which is to prepare science teachers for secondary school (KIE, 2009). The Faculty offers a 4-year degree programme consisting of lectures and practicals in the following subjects: Mathematics, Physics, Chemistry, Biology, Computer Science, Physical Education and Sport. It offers six Bachelor of Science (Hons) degrees with Education and Qualified Teacher Status (QTS), namely:

- B.Sc. (Hons) Mathematics with Education and QTS;
- B.Sc. (Hons) Physics with Education and QTS;
- B.Sc. (Hons) Biology with Education and QTS;
- B.Sc. (Hons) Chemistry with Education and QTS;
- B.Sc. (Hons) Computer Science with Education and QTS; and
- B.Sc. (Hons) Physical Education and Sports with Education and QTS.

For the four years courses are delivered in a modular system with five levels, described as follows. In the two first levels students take combinations of two science subjects with education, except for Computer Science and Physical Education and Sport, which are each considered as one subject. Thus, the Faculty of Science offers the following combinations in the two first levels: Mathematics-Physics with Education (MPE), Physics-Chemistry with Education (PCE), and Biology-Chemistry with Education (BCE), Computer Science with Education (CSE), and Physical Education and Sports with Education (PSE).

After completing the two levels, students continue their studies with one major Science subject and Education in a way that, for example, if a student in PCE chooses Physics as major subject, he/she will no longer study Chemistry at Levels 3, 4 and 5. After successfully completing Level 5, he/she will be awarded the degree of B.Sc. (Hons) Physics with Education and QTS. In this case Chemistry will appear on his/her transcript as a minor subject, stating that such a graduate can teach Physics at A level of secondary school, but he/she is also qualified to teach Chemistry at O level only. At each level there are a number of modules to study. Credits are allocated as follows: Level 1 – 120 credits, Level 2 – 120 credits, Level 3 – 60 credits, Level 4 – 60 credits and Level 5 – 120 credits. One credit equals 10 notional hours of student learning effort. Therefore, students need to have completed in total 480 credits for an honours degree (KIE, 2009).

Another route of training teachers to qualify for O level is a two years' full-time training in a college of education and a distance-training programme, both running under KIE supervision. The first offers the same combinations as for the BEd (Hons), but for only two years, and graduates qualify for teaching at O level only, while the latter intends to upgrade content knowledge in subjects that one teaches and improve his/her professional classroom skills. The second programme trains non-qualified secondary school teachers on a part-time basis by means of well-designed modules and face-to-face sessions with KIE tutors during school holidays in the 10 distance-training programme centres around the country. This training is relatively longer since it is a part-time programme, and may take up to four years. Those who take this route in either programme are awarded, after completion, a Lower Secondary Teacher Diploma, corresponding to what will later be called in this study A1.

It can be noticed that science teachers' training in Rwanda is a very recent enterprise, and that the country still has a long way to go even though significant efforts were made during the last decade. In fact, enrolment in lower secondary schools has almost doubled from 179153 in 2003 to 346518 in 2009 attaining a net enrolment rate of 95% as a result of the nine years of basic education programme which gained momentum following the recent school construction campaign, which saw thousands of new classrooms built across the country (MINEDUC, 2010). There are still significant challenges ahead for attaining corresponding qualified science teachers, and therefore reaching the Rwandan education system's mission. However, as acknowledged by a highly ranked official from the Ministry of Education, financing the increased number of teachers and teacher training programmes, integrating technology in schools for teaching and learning, and the future extension of secondary education, are all promising strategies but represent many challenges.

CHAPTER THREE

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

This chapter aims to review and discuss literature relevant to the present study and at the same time links this literature to the theoretical framework underpinning the research. The principal theory underpinning this study is the constructivism as learning theory, well known from the Piaget's work. The study is articulated around two concepts, namely 'inquiry-based science teaching and learning' as one of the teaching strategies designed to promote constructivist learning, and 'teachers' change with curriculum reform' that consists, in this study, of the introduction of inquiry-based science teaching into the O-level science curriculum in Rwanda, requiring teachers to adapt and respond to the new change.

Both teaching and learning of science in the present study are discussed within the constructivist view. To answer the research questions and interpret the results of the study, a theoretical framework is constructed based on the description of IBST from the literature that inspired the revision of the Rwandan O-level science curriculum. A chart below (Figure 3.1) represents the theoretical and conceptual framework pertinent to this study. It provides interconnections between key theories and concepts underpinning this study. The rationale behind this type of representation is to show explicitly the links between 'scientific inquiry and science process', 'teaching science through inquiry', 'teacher change with curriculum reform' and the data that are all about 'the teachers' responses to the introduction of IBST'.

Besides a brief introductory section, this chapter has four sections. The first, under the heading of 'Constructivism', discusses the constructivist theory of learning on the one hand and its place in science education with particular focus on instruction underpinned by constructivist ideas on the other hand. The second section discusses the concept of inquiry-based science with two main foci, namely scientific inquiry and science process, and teaching and learning science through inquiry. The third section is about teacher change with curriculum reform, and covers issues including some theories of change, curriculum change and factors influencing implementation as well as teacher change. The fourth and last is a brief concluding section provides the main points that emerge from the literature and forms a summary of the theoretical framework.

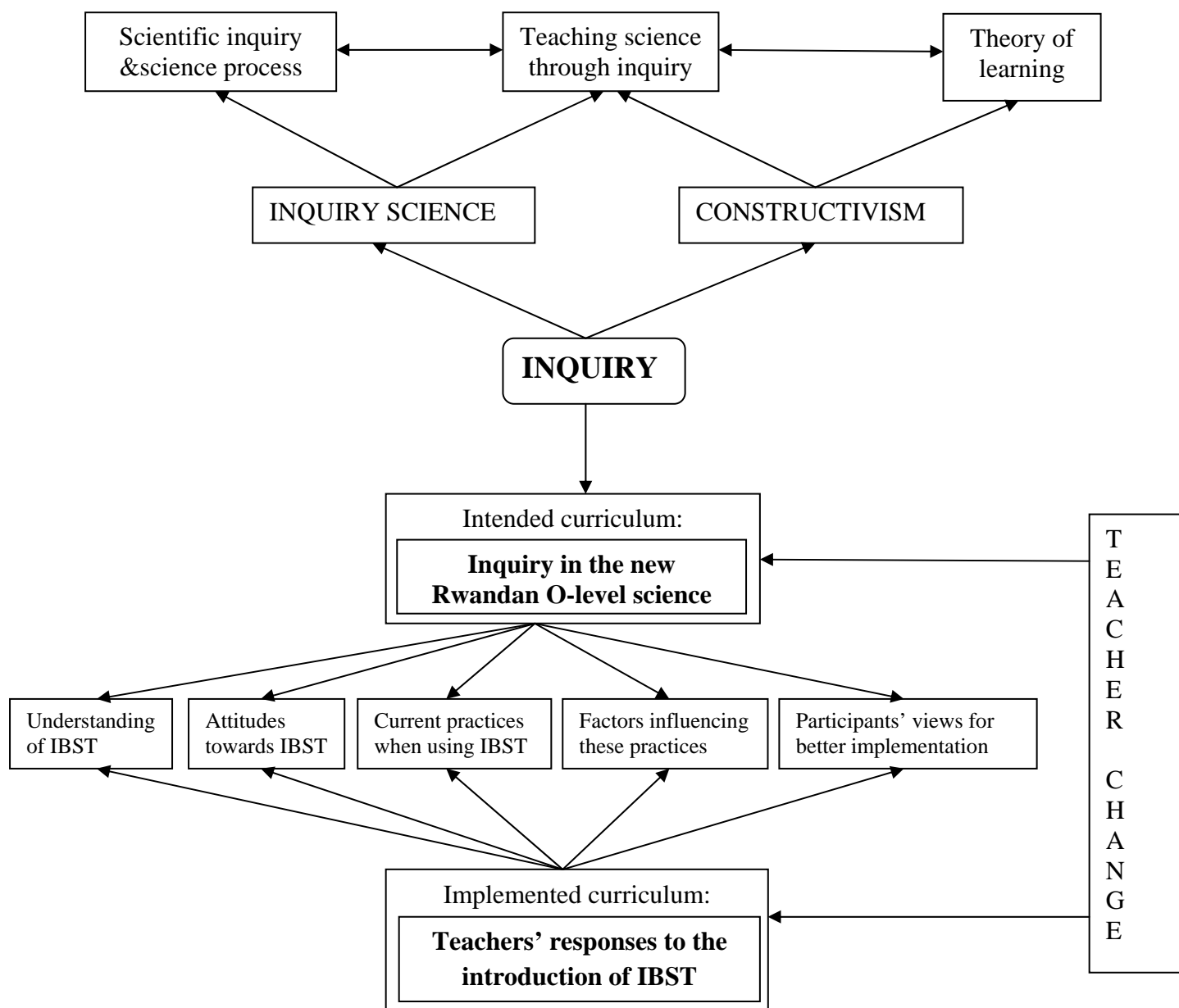


Figure 3. 1. Chart representing the theoretical and conceptual framework of the study

As can be seen, the research questions constituting the teachers' responses to the introduction of IBST as the focus of the study are at the interface between the actually intended and the implemented new Rwandan O-level science curriculum. Teacher change is a process they would go through in response to the change brought into the curriculum.

3.1. CONSTRUCTIVISM

In recent years characterized by important changes and reforms in education, constructivism seems to be one of the most debated learning theories, considering the significant influence it has gained including in science education. It has impacted on a number of national curricular documents and education statements (Matthews, 2002). As a result, it may be agreed that any curriculum that puts emphasis on inquiry is framed by constructivism, which is described as a more overarching theory that can incorporate a number of teaching practices, such as cooperative, collaborative, and inquiry-based learning (Seigel, 2004). Constructivism is discussed on the one hand as a theory of learning science, and on the other as a foundation of instructional strategies where particular attention is on the constructivist science classroom, which is relevant for an IBST approach.

3.1.1. Constructivist theory of learning

Although the constructivist perspective is not a new concept in education (Brooks & Brooks, 1999; Richardson, 2003; von Glaserfeld, 1995), Piaget is considered as the father of the constructivist school in the 20th century. His view that knowledge was constructed in the mind of the learner was based on research on how children acquire knowledge (Bodner, 1986). Later constructivism was seen as a type of learning theory that explains human learning as an active attempt to construct meaning of the world around us (Fritcher, 2008), with the following four key features:

1. Prior knowledge: in constructivism prior knowledge is taken into account and used as a base on which to construct further knowledge;
2. The knowledge is constructed: ideas and knowledge are not simply passed on from teacher to learner, instead learners create, construct or build their own understanding that fits into their previous ideas;
3. Learning is active: the active construction of knowledge is promoted when learners do something themselves rather than simply being told what they need to know; and
4. Learning depends on the social or physical environment that the learner is in.

There are as many varieties of constructivism as there are researchers (von Glaserfeld, 1995), but whatever type, the constructivist view primarily concerns a particular way of both conceptualizing and acquiring knowledge referring to learning (Duit, 2001). In the classroom context, the most commonly referred to varieties which is drawn upon when talking about inquiry-based science, as is the focus of this study, are: (a) cognitive or individual constructivism, also called endogenous constructivism, based on Piaget's theory; and (b) social or dialectical constructivism based on Vygotsky's theory.

These two types of constructivism have similarities and differences. Basically, the "fundamental nature of social constructivism is collaborative social interaction in contrast to individual investigation of cognitive constructivism" (Applefield, Huber & Moallen, 2001, p. 38). Piaget's approach is cognitive oriented and contends that a learner builds knowledge using his/her activities in the world, allowing him/her to make conclusions and make up their own mind. The learner's mental activity is the focus of Piaget's approach, and the teacher's intervention consists of creating the most suitable situations in which the learner can link his/her previous and current knowledge for learning to occur (Moore, 2004).

Piaget viewed knowledge as a process rather than a state, consisting of a relationship between the knower (learner) and the known (the knowledge). In this relationship the knower constructs his/her own representation of what is known (Martin, 2006). On the other hand, Vygotsky's approach claims that construction of knowledge is socially oriented (Cole & Wertsch, 2002) in the sense that learning occurs through interaction with and within the learner's social environment. Lev Vygotsky viewed learning as dependent on social and cultural factors, where students (knowers) construct knowledge through social interaction with each other, as pointed out by Martin (2006), arguing that "Vygotsky was a social constructivist who believed that learners could and should utilize the input of others as they formulate their construction and not rely solely on themselves" (p. 195). While Piaget's and Vygotsky's views seem to be opposite (as the former considers the direction of the development of thinking from the individual to the social and the latter sees it from the social to the individual), they are not. In fact, Piaget has never denied the role of the social world in the construction of knowledge, and Vygotsky does not ignore the mental activity and reflection of the individual (Cole & Wertsch, 2002). They are both constructivists, the only difference between their schools of thought being the fact that Piaget emphasized the

individual nature of learning whereas Vygotsky emphasized the social nature. Other similarities include inquiry teaching methods and students creating concepts built on existing knowledge that is relevant and meaningful, while differences include language development theory whereby thinking precedes language for cognitive constructivism and language precedes thinking for social constructivism (Powell & Kalina, 2009).

Despite such a variety of versions, constructivism is seen as a driving theory of learning in modern education and more particularly in science education, where it is used to guide the development of new teaching methods (Baviskar, Todd, Hartle & Whitney, 2009). The most shared interpretation of what constructivism means is the change in the focus of teaching, putting the learners' own efforts to understand at the centre of the educational enterprise, which in the context of the present study has a focus on inquiry. As a theory of learning it is based on the four characteristics considered as those most influencing learning namely: (a) learners construct their own knowledge; (b) the dependence of new learning on students' existing understanding; (c) the critical role of social interaction; and (d) the necessity of authentic tasks for meaningful learning (Applefield, Huber & Moallen, 2001).

Based on these characteristics and the focus sketched above, it can be argued that the constructivist theory of learning is widely accepted as the most popular underpinning instructional reform in science education in the world today, in addition to the great attention it received in the past decade (Richardson, 2003). This view is emphasized through Murphy's (1997) statement that "central to constructivism is its conception of learning" (n.p). This theory of learning focuses on the learner and learning, not on the teacher conducting a lesson at a particular moment, the goals of instruction and skills required or the displayed behaviours of learners (Ryder, 2005). As a theory of learning, constructivism is often opposed to the behaviourist model of learning, which centres on learners' efforts to accumulate knowledge of the natural world and on teachers' efforts to transmit it (Murphy, 1997).

Many researchers and educators share the idea that from the constructivist perspective, learning is not a stimulus-response phenomenon. Instead it requires self-regulation and abstraction and focuses on concept development and deep understanding, rather than on behaviours or skills as the goal of instruction (Fosnot, 1996). Therefore a constructivist believes that learners must construct meaning themselves and, as a result, any

learning takes place when it is “connected to the individual’s already existing knowledge, experiences or conceptualization” (Martin, 2006, p. 183).

To understand what knowing means and how one comes to know something is framed in constructivism. In this regard Fosnot (1996) argues that reality is not knowable but is a theoretical construction. In the context of knowledge acquisition, whether in school or out of school or more generally in individual daily lives, Bodner (1996) contends that “Piaget believed that knowledge is acquired as the result of a life-long constructive process in which we try to organize, structure, and restructure our experiences in light of existing schemes of thoughts, and thereby gradually modify and expand these schemes” (p. 874). Within this process, Duit (2001) brings in the two concepts that constitute the essence of constructivism, namely the conceptualization of knowledge based on a certain epistemology and the acquisition of knowledge as a way of learning. All these ideas brought together can be extended to describe a constructivist view of knowledge acquisition as an active process of meaning-making based the use of prior knowledge and new information as experiences. In this process of meaning-making the two complementary phenomena, namely assimilation and accommodation, sometimes take place through the intermediate situation of disequilibrium followed by equilibration in the best of cases (Bodner, 1986). He further distinguishes what he calls cognitive functions and cognitive structures, referring to the constancy throughout the development of organization and adaptation for the former, and the qualitative and quantitative changes that occur with age and experience for the latter.

The following chart (Figure 3.2) summarizes Piaget’s proposed model of knowledge acquisition through the above described sequence. From this model it appears that disequilibrium occurs when individuals cannot assimilate their experience into pre-existing schemes or when they encounter problems in achieving their instructional goals. Equilibration is then restored by modifying these existing schemes until the discrepancies are resolved, enabling them to fit the newly assimilated information that allows accommodation to take place.

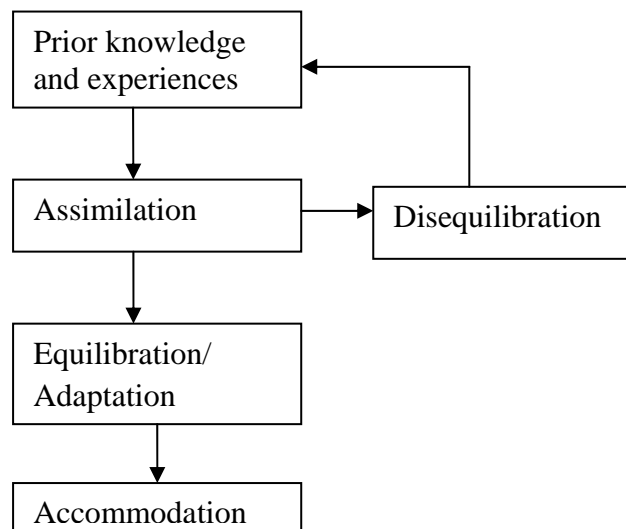


Figure 3. 2. Piaget's proposed model of knowledge acquisition

It can therefore be asserted that the individual background coupled to previous experience is the foundation of effective learning. This idea is supported by Applefield, Huber and Moallen (2001), who contend that “for the learner to construct meaning, he or she must actively strive to make sense of new experiences and in so doing relate it to what is already known or believed about the topic” (p. 38). This can be achieved in a number of ways which support the construction of a block of understanding that is based on provided information and past experiences, purpose and interests. In an attempt to fully understand the way learning takes place constructively, Bonk and Wisher (2000, p. 6) provide a synthesis of the characteristics of constructivist learning, as follows:

1. Learning is conducted from the experience of the learner and builds on prior knowledge in order to make it relevant and meaningful;
2. Interpretation is personal;
3. Meta skills to manage one’s learning are reflected upon to address misconceptions in thinking;
4. Learning is an active process whereby experience is converted into knowledge and skills;
5. Learning is collaborative and social, thus allowing for multiple perspectives;
6. Knowledge is situated in real-life, which is ideally where learning should take place; and
7. Assessment should be integrated with the task.

Thus, in order to ensure that learners have understood, instead of simply being able to repeat what the teacher or the textbook have said they should respond in a way that is compatible with the teacher's understanding. Even though constructivism may be seen as a theory about learning rather than a description of teaching, there is an obvious relationship between theory and practice, with important pedagogical implications. Drawing from the fundamental constructivist principles of learning, Applefield, Huber and Moallem (2001, p. 51) suggest the following list of pedagogical recommendations with regard to constructivism:

1. Learners should be encouraged to raise questions, generate hypotheses and test their validity;
2. Learners should be challenged by ideas and experiences that generate inner cognitive conflict disequilibrium. Students' errors should be viewed positively as opportunities for learners and teachers to explore conceptual understanding;
3. Students should be given time to engage in reflection through journal writing, drawing, modelling and discussion. Learning occurs through reflective abstraction;
4. The learning environment should provide ample opportunities for dialogue and the classroom should be seen as a "community of discourse engaged in activity, reflection, and conversation";
5. In a community of learners, it is the students themselves who must communicate their ideas to others, defend and justify them; and
6. Students should work with big ideas - central organizing principles that have the power to generalize across experiences and disciplines.

To sum up, it is important to recall that despite the extensive literature on constructivism and the complexity of its various forms, there is a common ground putting emphasis on the necessity for active participation by the learner together with common recognition of the social nature of learning. As pointed out by Confrey (1990), many types of constructivism are modern forms of progressivism which, when applied to the issue of teaching, reject the assumption that one can simply pass information to a set of learners and expect that understanding will result.

Therefore, the accomplishment of the educational goal of stimulating of thinking in learners, resulting in meaningful and deeper understanding together with a transfer of learning to real-world contexts, is possible in a constructivist framework. Such a framework is entirely consistent with an inquiry approach, since it is acknowledged that one of the

advantages of inquiry-based teaching is that it enables students to learn in a constructivist way.

3.1.2. Instruction underpinned by constructivist ideas

Modern science reflects the ideas of constructivism and contains many of the features of constructivism. Therefore, the best way of teaching science is to use these constructivist ideas. The use of inquiry, especially in teaching science, seems the most prominent considering that one of the advantages of IBST is that it enables students to learn in a constructive way. In supporting this teaching underpinned by constructivism, Duit (2001, p. 1) gives strong emphasis to the popularity of constructivism in science education, arguing that:

There is certainly something fashionable about constructivism in science education nowadays and without any doubt it has become a most valuable guideline for science educators - for science teaching and learning as well as research in these fields. It is furthermore true that constructivism is by no means a consistent movement that appears, for some educators, in any cases, as a new ideology of science education which provides a cure for every problem in teaching and learning science.

Constructivist ideas underpinning science teaching vary considerably. For example, Good, Wandersee and Julien (1993) make the point that the constructivist view comes in many variants in science education literature on students' learning. However, despite such a variety of views, the common constructivist core is human knowledge that Taylor (1993) describes as "a process of personal cognitive construction, or invention undertaken by the individual who is trying to make sense of his/her social or natural environment" (p. 268), and for these reasons constructivism seems to have gained significant popularity in science education, mainly consisting of making sense of the natural world.

In the same perspective, Brooks and Brooks (1999) goes on to make the point that while a lot of people try to look at constructivism as a programme, a methodology or a series of techniques, it is really a life view. She sees constructivism as a way of looking at teaching and learning; briefly a way of looking at how people construct understanding of our world,

which is the core scope of learning science. Through literature, many researchers have studied and written about practical approaches to education based on constructivism, while more particularly theorists suggest links between constructivist theory and what is actually done in practice by providing the beginning of an orienting framework for a constructivist perspective to design teaching or learning (Murphy, 1997).

To cite but a few, some related works designing teaching strategies that promote constructivist learning have emerged in the early 1990s, including Ernest (1995); Honebein (1996); Jonassen (1991, 1994); von Glaserfeld (1995); Wilson and Cole (1991); and Yager (1991). Among other ideas, they most discussed the implication of constructivism for instructional design, the goals for designing a constructivist learning environment, and the description of cognitive teaching models which embody constructivism concepts.

From an instructional point of view, constructivist learning environments are more open in the sense that they allow the learner freedom to engage with a variety of resources and to build on prior knowledge and experience to solve a problem or do a project referring to the degree of learners' autonomy when involved in inquiry-related activities. In this regard one can assume that learners do this intuitively where they improvise in any given learning situation, by involving mental schemata, experience, intuition, other people as well as a variety of resources to solve problems. This does not apply to memorizing information or solving textbook problems, where the answer can often be constructed from a textbook. It rather refers to solving unstructured problems (Karen, 2002). This understanding of learning from the constructivist perspective enables making the distinction between meaningful and rote learning, as follows:

To learn meaningfully, individuals must choose to relate new knowledge to relevant concept and proposition they already know. In rote learning ... new knowledge may be acquired simply by verbatim memorization and arbitrarily incorporated into a person's knowledge structure without interacting with what is already there. (Bodner, 1986, p. 877)

When applied to science, learning from the constructivist perspective may be viewed in terms of students' pathways from certain pieces of their already existing conceptual structure (prior knowledge and experience) towards science conception. In fact, constructivism suggests that as we experience something new, we internalize it through our

past experience or knowledge construct we have previously established, as advocated by Penner (2001), arguing that “learning activities begin by considering the role of students’ current knowledge, how knowledge is constructed, and the role of the activity in building knowledge” (p. 3).

In the constructivist classroom there are several most common practices. In fact, even in the classroom the constructivist view of learning supposes a number of different practices; the most general sense is that students are encouraged to use active techniques to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. As for constructivist teachers, they pose questions and problems, and then guide students to help them find their answers, which are actually at the core of the inquiry teaching approach. Thus, in the constructivist classroom, learning is (Seigel, 2004):

1. *Constructed*: Students are not blank slates upon which knowledge is etched;
2. *Active*: Students are persons who create new understanding for themselves;
3. *Reflective*: Students control their own learning process and lead the way by reflecting on their experiences;
4. *Collaborative*: The constructivist classroom relies heavily on collaboration among students;
5. *Inquiry-based*: Students use inquiry methods to ask questions, investigate a topic and use a variety of resources to find solutions and answers; and
6. *Evolving*: Students have ideas that they may later see were invalid, incorrect, or insufficient to explain new experiences.

Thus, science education from this constructivist perspective provides students with science knowledge in such a way that they understand not only the science concepts and principles, rather than learning definitions and formulas by heart, but also understand in which way science knowledge is of significance for their lives (Duit, 2001). However, there is a need for further evidence as to how students actually understand scientific phenomena (Jenkins, 2000).

Considering the above characteristics of a constructivist classroom, it seems obvious that it differs from the traditional classroom, both from the viewpoint of the learner and the teacher, as well as in its basic assumptions. In the constructivist classroom both teacher and learners think of knowledge not as inert factoids to be memorized, but as a dynamic, ever-

changing view of the world and the ability to successfully stretch and explore that view (Educational Broadcasting Corporation, 2004).

In a traditional setting, the teacher takes charge of a lot of the intellectual work in the classroom. The teacher plans the scope and sequences, pre-synthesizes and pre-packages a lot of learning. In the constructivist classroom the student is in charge of that pre-packaging. The student gets amorphous information and ill-defined problems, and then has to put together his/her own personal question and figure out how to go about answering it with the teacher being the mediator of that meaning-making process (Brooks & Brooks, 1999).

Table 3.1 below provides a comparison between the two types of classrooms in various aspects, including the two opposite ways in which teacher and learners shift into their responsibility, the curriculum, as well as the handling of teaching materials

Table 3. 1. Comparison of the traditional and constructivist classroom

Traditional classroom	Constructivist classroom
1. Curriculum begins with the parts of the whole. Emphasizes basic skills	1. Curriculum emphasizes big concepts. Beginning with the whole and expanding to include the parts
2. Strict adherence to fixed curriculum is highly valued	2. Pursuit of student questions and interests is valued
3. Materials are primarily textbooks and workbooks	3. Materials include primary sources of materials and manipulative materials
4. Learning is based on repetition	4. Learning is interactive, building on what the student already knows
5. Teachers disseminate information to students; students are recipients of knowledge	5. Teachers have a dialogue with students, helping them construct their own knowledge
6. Teacher's role is directive, rooted in authority	6. Teacher's role is interactive, rooted in negotiation
7. Assessment is through testing, correct answers	7. Assessment includes student works, observations, and point of view as well as tests. Process is as important as product
8. Knowledge is seen as inert	8. Knowledge is seen as dynamic, ever-changing with our experiences
9. Students primarily work alone	9. Students primarily work in groups

Source: Educational Broadcasting Corporation (2004), adapted from Duit (2001).

Contrary to criticism from some conservative educators, constructivism does not dismiss the active role of the teacher (Seigel, 2004). Instead, it modifies this role by assigning a teacher the role of helping students to construct knowledge rather than reproducing a series

of facts. By so doing, a constructivist teacher provides tools such as problem-solving and inquiry-based learning activities with which students formulate and test their ideas, draw conclusions and inferences, and convey their knowledge in a collaborative environment. Teachers become facilitators who engage and guide their students in exploratory and discovery activities by providing necessary scaffolding to assist learners in developing new insights and connecting them with their previous knowledge or learning. They are no longer classroom leaders who traditionally used to direct memorization or repetition drills. As a result of this a new way of considering the interaction between teacher and learner, constructivism transforms students from passive recipients of information to active participants in the learning process. Always guided by the teacher, students construct their knowledge actively rather than just mechanically ingesting knowledge from the teacher or the textbook.

Although there are specific teaching methodologies that are strongly constructivist, such as inquiry-based teaching methods, it is not necessary to use one of these methods to be constructivist. Baviskar, Hartle and Whitney (2009, pp. 543-544) point out four critical elements that must be addressed for a lesson to be constructivist:

1. *Eliciting prior knowledge* as a criterion based on the presupposition that all knowledge is acquired in relation to the prior knowledge of the learner. Prior knowledge can be elicited in different ways, including formal pre-tests, asking informal questions, formal interviews with students or setting activities such as concept-mapping that requires basic knowledge to be applied;
2. *Creating cognitive dissonance* by making the learner aware of the difference between his/her knowledge and the new knowledge;
3. *Application of the knowledge with feedback* that enables the student to integrate the new knowledge permanently. The application of the new construct could be in the form of quizzes, presentations, group discussions or other activities where the students compare their individual constructs with their group members or with new situations; and
4. *Reflection on learning* as a students' opportunity to express what they learnt. This could be attained using traditional assessment techniques such as presentations, papers or examinations.

In a more detailed manner, Driver (1989) also refers to these criteria and proposes a constructivist teaching sequence as follows:

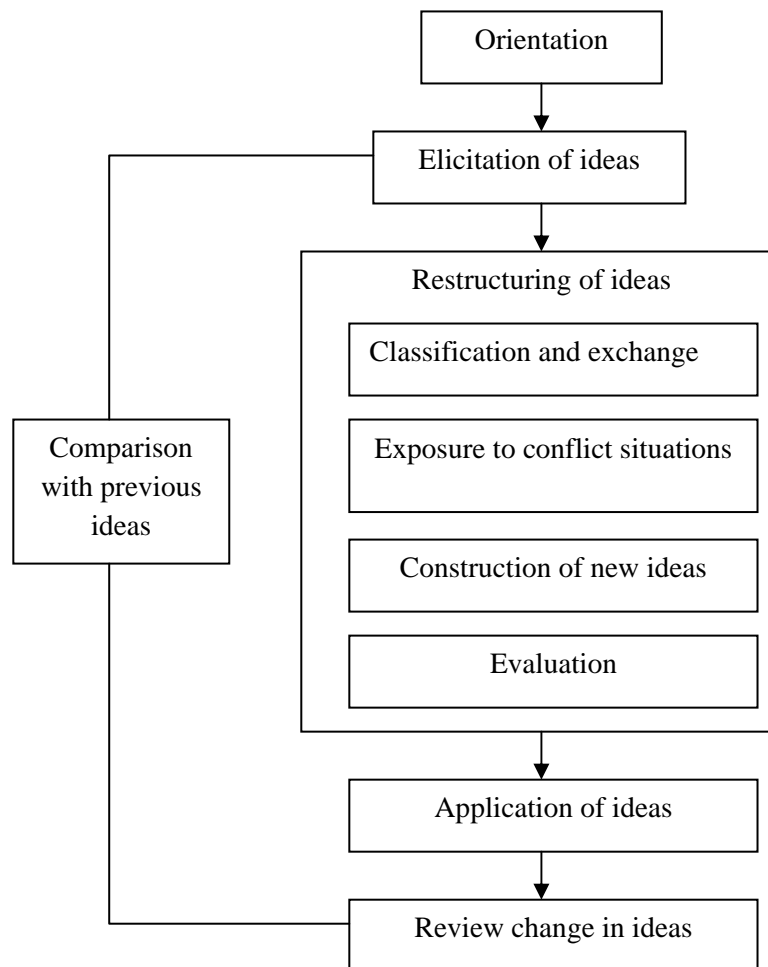


Figure 3. 3. The constructivist teaching sequence (adapted from Driver, 1989, p. 88)

The benefits and usefulness of constructivist ideas in science teaching and learning are widely acknowledged, but at the same time are subject to severe criticism. The literature has extensively discussed the usefulness of teaching methods based on constructivist views which are considered very helpful for students' learning, thus justifying the important place they have recently gained. For example, Haney, Lumpe and Czerniak (2003) argue that constructivist views about learning have gained acceptance among educators as a viable framework for understanding learning and developing models of effective teaching. Furthermore, research findings indicate a number of benefits in the constructivist classroom. It is argued that the use of constructivist approaches promotes critical thinking and collaborative learning, and increases student engagement. It also develops communication

and social skills, encourages alternative methods of assessment, helps students transfer skills to the real world, and promotes an intrinsic motivation to learn. Another big benefit of constructivism is that learners will learn to apply their knowledge under appropriate conditions.

The social aspect of constructivist learning is also important because of the fact that collaborative methods of learning develop critical thinking through directing learners towards discussion, clarification of their ideas and evaluation of others' ideas (Pulkkinen & Ruotsalainen, 1997). Above all, constructivist methodology promotes the act self-motivated, self-directed learning to begin a lifelong quest for new skills and knowledge. Even the USA, that has attained high achievement in science education, has included constructivist ideas in most of their national science reform recommendations during the last decade. Reference can be made to the National Science Education Standards (NSES), project 2061: Science for All Americans, and the Biology Science Curriculum Study organization. This does not, however, mean that constructivist approaches are free from criticism, as discussed below.

Although it is widely accepted that constructivism has been highly influential in the field of science education, it has not been without criticism. For example, in his book entitled *Progressing Science Education*, Taber (2009) devoted a full chapter to the criticism of constructivism in science education, examining and discussing six areas of criticism (pp. 147-148), claiming that: (a) constructivism is based on false premises and misleading metaphors about learning, (b) constructivism in science education has a confused philosophical basis and offers a relativist view of science, (c) constructivist research is theoretical and/or makes use of invalid or unsupported theoretical constructs, (d) an approach based on personal constructivism is inappropriate as learning should be understood in social and collective not individual terms, (e) while research has produced a great deal of literature, it has had minimum impact on educational practice, and (f) the constructivist approach has ceased to offer useful insights. For him, constructivism should now be abandoned for more promising approaches.

Furthermore, in a special issue of the *Interdisciplinary Journal of Constructivist Foundations*, Boden (2010) authored a chapter entitled 'Against Constructivism'. He acknowledged that although it is an accepted fact that 'scientific concepts are generated and constructed in human minds as supported by constructivism, it cannot be denied that realism

is the foundation of many well-proven processes in science and engineering' (p. 84).
 Kirchner, Sweller and Clark (2006) also pointed out that the minimum guidance supported by constructivism is not efficient or effective compared to most guided instruction. Moreover, despite their sympathy with constructivism, Tobias and Duffy (2009) found that the lack of empirical evidence for the effectiveness of constructivist teaching methods turned constructivism into a theoretical model rather than a pedagogical method. From the same perspective, the constructivist approach is also charged that it only works best with students from privileged backgrounds who already possess essential skills and school-oriented attitudes and behaviours.

Another criticism goes to the overuse of collaborative and constructivist strategies, which can lead to what is called 'group think; and discourage independent thinking and creative problem solving by highly talented individuals (Educational Broadcasting Corporation, 2004). Finally, Merrill (1991) pointed out two major disadvantages of constructivism: first, learners may be hampered by contextualizing learning in that they may not be able to form abstractions and transfer knowledge and skills in new situations, and as a result get confused or frustrated; and second, learners can enjoy this approach of discovering learning, but do not always actively construct meaning and build an appropriate knowledge structure. As a result, they may end up simply copying what better students do.

Considering both features and criticisms, it seems that the teacher engaged in a constructivist teaching approach has to play the critical role of finding the right mix of methods for optimizing the students' benefits. For that to happen, the teacher makes use of a number of strategies. Martin (2006) lists but a few, asking questions to see how learners may have previously constructed information related to the topic, engaging learners into exploratory activities that enable them to investigate on their own and come to their own conclusions, interacting with each learner to see how he/she is constructing the new information, and helping them to formulate sound and meaningful conclusions. In this regard Brooks and Brooks (1999) identified a number of teaching descriptors that are appropriate for any constructivist classroom and Martin (2006, p. 196-197) referred to these descriptors and listed a number of activities that a constructivist teacher engages in, including to:

1. Encourage and accept student autonomy and initiative;
2. Use raw data and primary information sources with manipulative, interactive, and physical materials;
3. Use cognitive terminology such as classify, analyze, predict and create;
4. Allow student responses to drive lessons, shift instructional strategies, and alter content;
5. Inquire about students' understandings of concepts before sharing their own understandings about the concepts;
6. Encourage students to engage in dialogue, both with the teacher and with one another;
7. Encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other;
8. Seek elaboration of students' initial responses;
9. Engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion;
10. Allow waiting time after posing a question;
11. Provide time for students to construct relationships and create metaphors; and
12. Nurture students' natural curiosity through frequent use of the learning cycle model.

To fulfil this critical role, science teachers should be aware of the current unprecedented increasing rate of scientific knowledge, and stay updated. For this to happen, among other strategies relevant science teacher professional programmes are most suitable and recommendable. However, O-level science teachers do not need to master a huge amount of facts, concepts and theories about science. Instead, they need to know how children learn science and how to teach them (Martin, 2001). An emphasis was made with this regard by Yager (1993), arguing that “apparently what a teacher does and how he/she does it in the classroom is far more important than what he/she knows or the curriculum he/she uses” (p. 146).

To sum up, views of a number of authors about constructivist-based teaching has been provided. The pros and cons were identified, but the common denominator is that “constructivism shifts the focus of attention from the propositional ‘knowing that’ to the pragmatic ‘knowing how’” (Riegler, 2005, p. 4), which is central to learning science. The Rwandan O-level science curriculum which introduced the IBST approach was partially guided by such a shift. A look at commonalities emerging from distilling this common denominator comes up with a framework used to represent constructivist teaching. Seigel’s (2004) characteristics of a constructivist classroom, Baviskar, Hartle and Whitney’s (2009) four critical elements that should be addressed for a lesson to be constructivist, and Martin’s

(2006) list of activities that constructivist teachers engage in are used in this study for describing constructivist teaching.

Despite the controversial discourse around theories of learning, as far as I am concerned I firmly believe that constructivism is the best framework for understanding and interpreting issues around teaching and learning, including the use of IBST, which is discussed in the next section.

3.2. INQUIRY-BASED SCIENCE

“If a single word had to be chosen to describe the goals of science educators during the 30-years period that began in the 1950s, it would be INQUIRY” (DeBoer, 1991, p. 26).

The purpose of this study was to explore teachers’ responses to the introduction of an IBST approach at lower secondary school. As mentioned earlier in this chapter, IBST, which is constructivist in nature, is central to the study and is therefore discussed in this section as part of the theoretical framework. In this section, after briefly presenting the historical development of and an attempt to define the concept of inquiry, a rapprochement between scientific inquiry, science process and scientific method is made since most of their respective components interchangeably take place when implementing inquiry teaching and learning approach. Lastly, an important sub-section discusses issues related to the teaching and learning of science through inquiry.

Increasingly in recent years, many science education curriculum developers have placed more emphasis on learning science through inquiry (NRC, 2000). Within many reforms that a number of educational systems have undergone in the last few decades, inquiry has persistently been seen as representing the essence of science education (Keys & Bryan, 2001) and as a central word to characterize good science teaching and learning (Anderson, 2002). In his paper entitled ‘*A brief history of inquiry: From Dewey to standards*’, Barrow (2006) provides a historical perspective of inquiry. Persuaded that there was much emphasis on facts, with less consideration of teaching science for thinking and promoting an attitude of mind, Dewey was the first to recommend the inclusion of inquiry into the science curriculum early last century, after criticizing the way science was taught “before 1900 where most

educators viewed science as primarily a body of knowledge that students were to learn through direct instruction” (NRC, 2000, p. 14). Since then to date, inquiry went through various steps that can be summarized into three major eras, with multiple changes within each of them.

The first circle of influence was centred on Dewey’s model, dated from around 1909 and prevailed during the first half of the last century. Central to this model was, from then, the students’ active involvement and the teacher’s role shift to that of facilitator and guide. Through the course of time the model was progressively refined, shaping the new way of teaching and learning science. The second was essentially based on Schwab’s thoughts about inquiry science in the 1960s; this laid the foundation for the emergence of inquiry as a prominent theme in the curriculum reform of that era (NRC, 2000). For him “the rationale for inquiry as an approach to teaching science was becoming increasingly evident” (p. 15). Schwab’s ideas also went through a number of important adaptations, and the subsequent changes of the 1950s, 1960s and 1970s widely disseminated the idea of helping students to develop the skills of inquiry and an understanding of science as inquiry. According to Bybee (2000), in 1958 Joseph Schwab grounded in science itself his argument for teaching science as inquiry, claiming that “the formal reason for a change in present methods of teaching the sciences lies in the fact that science itself has changed and that the new view concerning the nature of scientific inquiry now controls research” (p. 27). This circle of influence led to the third era of inquiry science in the mid-1990s, with the publication of the National Science Education Standards (NSES), whose developers were committed to include mainly inquiry both as science content and as a way to learn science (NRC, 2000).

Today inquiry is increasingly earning a substantial place in the science curriculum of many developing countries. However, in Rwanda it is at a very early stage of its adoption. There is therefore a real need to learn more about how it is being implemented, especially how teachers respond to its recent introduction into the lower secondary school science curriculum, which is the main focus of this study. Before engaging in deep discussion, it is worth defining the concept in order to frame an understanding from which to draw a description that would be most relevant to this study. In the light of related existing literature this will enable one to set up a framework guiding this study and the lens through which IBST and learning at lower secondary school in Rwanda is discussed and interpreted.

Although the term “inquiry” is not new in the discourse of science education, until now there has been a lack of agreement on the meaning of inquiry in the field of science inquiry (Martin, 2001; Minstrell and Van Zee, 2000). This is further emphasized by Barrow (2006), arguing that over the last century inquiry had multiple meanings, but expressing the hope that in the first decade of the 21st century a consensus about what inquiry is could be reached. The variety of its meaning is further highlighted by Wheeler (2000), who described it as “an elastic word, stretched and twisted to fit people’s differing worldviews” (p. 14). As a result, both teachers and science educators have multiple interpretations of inquiry as a teaching and learning approach.

When you look up at the term “inquiry” in a number of dictionaries, such as the *American Heritage Dictionary of English Language* or the *Collin English Dictionary*, you find that it means posing of questions, finding out something, and the search for information or the carrying out of an investigation. *Webster’s Third International Dictionary* (1996) defines ‘inquiry’ as “an act or an instance of seeking for truth, information or knowledge, investigation, research, or a question or query”, and indicates that the roots of the word ‘inquire’ mean “to ask for information or questioning” (p.1167). Furthermore, the NRC (1996) associates the concept ‘inquiry’ to that of ‘science’, and provides a more detailed definition that constitutes the foundation of its application in science learning, posing that:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations; and communicating the results. (p. 23)

In the same perspective, the Exploratorium’s website provides a synopsis of inquiry, arguing that the inquiry process is driven by one’s curiosity, wonder, interest or passion to understand an observation or solve a problem, and as it relates to science education inquiry should mirror as closely as possible the enterprise of doing real science (Ash & Klein, 2000). They describe it as an approach to learning that involves a process of exploring the natural or material world that leads to asking questions and making discoveries in the search for new understandings.

From this variety of definitions of inquiry, Colburn (2000, p. 42) goes along with this point and argues that “perhaps the most confusing thing about inquiry is its definition since the term is used to describe both teaching and doing science”. Therefore, inquiry is viewed from different perspectives. On one hand, it is seen as how scientists conduct science, referring to science process skills, and on another hand as a teaching and learning approach, referring to its implementation in a science classroom, including how students learn science and about how science works (NRC, 2000). The same dichotomous view was further highlighted in the National Science Education Standards (NSES), where the concept of inquiry and inquiry-based science interweave, since inquiry is considered on the one hand as how scientists conduct scientific inquiry and on the other how students learn science and how scientists work (Walker, 2007). With regard to this last view, Minstrell, 2000 (cited in Barrow, 2007) adds another dimension of inquiry, that includes “encouraging inquisitiveness, a teaching strategy for motivating learning, hands-on and minds-on practical work, manipulating materials to study particular phenomena, and stimulating questions by students” (p. 265).

Despite this variety of views, there is one common aspect that covers both perspectives. This aspect can be drawn from Audet’s (2005) interpretation, pointing out that “the legion of data, beliefs, definitions, and description of inquiry all boil down to one: Inquiry is any activity aimed at extracting meaning from experience” (p. 6). The description that the Rwandan O-level science curriculum gives to inquiry is informed by the abovementioned description. It focuses on the interaction with real phenomena through practical observation and manipulation for promoting the development of logical, scientific, operational and creative capabilities through acquisition of fundamental and specific knowledge (MINEDUC, 2007b). It is on this basis that inquiry was interpreted in this study and the framework developed.

3.2.1. Scientific inquiry and the science process

For several decades the concept ‘inquiry’ has been used to describe what scientists did when trying to understand the world and conducting experiments. However, today modern words such ‘research’, ‘investigation’ or simply ‘study’ have taken over from inquiry as used to describe the work of scientists. When conducting research scientists use a number of skills, known as science process skills, and follow a number of steps generally known as the ‘scientific method’. Used in a methodical sequence, these skills include observation, description, questioning, planning of experiments, predicting, and experimentation (NRC, 1996). This methodical aspect may lead to a question whether there is a relationship between the scientific method and the inquiry process and how they can be applied in a teaching and learning context. Table 3.2 illustrates the different components of the scientific method, the inquiry process and science process skills.

Table 3. 2. Scientific method, inquiry process and science process skills

Scientific method⁽¹⁾	Inquiry process⁽¹⁾	Science process skills⁽²⁾
Question or problem	Inquiry phase (inquiry or problem)	Observe
Hypothesis	Data gathering I (hypothesis)	Experiment
Experiment	Data gathering II (data collection & analysis)	Collaborate
Record		Measure
Data analysis	Implementation phase (conclusion & explanations)	Sort/classify
Conclusion		Compare
		Record
		Analyse & share

Adapted from ⁽¹⁾Chen, J. (2007). *Science Inquiry*; ⁽²⁾ National Association for Research in Science Teaching (2011). *The Science Process Skills*.

Table 3.2 reveals that science process skills are not used exclusively by scientists; they are transferable and can be used in the teaching and learning context, which is the essence of teaching and learning through inquiry. The major difference between the scientific method and the inquiry process is that the latter provides learners more opportunities to move within and among the phases of inquiry. Therefore, inquiry-based science learning consists of learners moving methodically through inquiry process steps while applying the science process skills and this is relevant as far as the Rwanda O-level science curriculum is concerned.

The American Association for the Advancement of Science (AAAS) has developed a more comprehensive description of science process skills. It put them into two categories, namely basic and integrated process skills, based on their level of complexity and difficulty

for the purpose of teaching and learning, together with the different abilities of learners at different age ranges (Martin, 2006).

The basic science process skills include:

1. **Observation**, consisting of scientists using their senses to observe and make sense of the world around them;
2. **Classifying**, consisting of grouping and ordering objects into categories;
3. **Measuring** as describing the specific dimensions of an object, an event or phenomenon;
4. **Communication** as describing an observed object, event or phenomenon to others;
5. **Inferring**, consisting of the drawing a conclusion as to why something occurs, based on collected data; and
6. **Predicting**, consisting of making an educated guess about some future events, based on what has already been seen.

The integrated science process skills include:

1. **Controlling** variables, consisting of identifying variables and then controlling them;
2. **Defining operationally**, consisting of the identification of measurements to be used in the experiments, such as what to measure or how many measurements to do;
3. **Formulating hypotheses**, similar to making a prediction as to what the expected outcome of the experiment is;
4. **Collecting data**, being a systematic gathering of information;
5. **Interpreting data**, including the organization, analysis and interpretation of information;
6. **Experimenting**, as the designing of an experiment to test some hypothesis; and
7. **Making models**, consisting of the use of information to make a simulation of some event or observation.

As it can be seen, the basic science process skills are relevant to young learners while the integrated fit better to middle and high school learners; inquiry-based science offers learners a chance to use a range of these skills. Since this study is concerned with lower secondary school in Rwanda, the ‘integrated science process skills’ are the most relevant here, although from time to time I will be considering the basic ones, especially for lower grades as they were envisaged in the revised science curriculum. Subsequently, teaching science through inquiry involves teaching students the science processes and skills used by scientists to learn about the world and to help these students apply these skills in learning science concepts (McBridge, Bhatti, Hannan & Feinberg, 2004). This view is given much

emphasis through Bybee's (2004) statement that "inquiry as a teaching strategy should capture that spirit of scientific investigation and the development of knowledge about the natural world" (p. 9).

By applying these skills in science education, another more complex dimension of learners familiarizing themselves with how science works takes place. That dimension also points out the process characteristics of inquiry, as viewed by the NRC (2000) in describing inquiry as:

... a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories . . . students will learn science in a way that reflects how science actually works. (p. 214)

Some findings from the NRC, as summarized by Chen (2008), are relevant to inquiry and constitute some of its main features. These are as follows (Chen, 2008, p. 6):

1. Understanding science is more than knowing facts;
2. Students build new knowledge and understanding based on what they already know and believe;
3. Students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know;
4. Learning is mediated by the social environment in which learners interact with others;
5. Effective learning requires that students take control of their own learning; and
6. The ability to apply knowledge to novel situations is affected by the degree to which students learn with understanding.

Although Schwab's ideas with regard to inquiry as an approach to teaching science (NRC, 2000) are a bit outdated, they are shared by many contemporary authors and are still seen as relevant in recent works such as those by Linn, Clark and Slotta (2003), Oates (2002) and Songer, Lee and McDonald (2003). These ideas suggest that upon using science as inquiry strategies, teachers involve students in inquiry-based activities but do not predetermine science concepts for students to discover (as does a cookbook). Instead, teachers involve students in investigations aiming at (a) challenging the validity of currently accepted concepts, (b) going beyond their present understanding of currently accepted science concepts, and (c) investigating differing explanations for specific science phenomena

(McBride et al., 2004, p. 435). This is quite similar to how Willoughby (2005) describes inquiry-based instruction, arguing that it involves creating situations in which students take the role of scientists.

Although it is important to note that there is not one single scientific method but several scientific methods, like inductive and deductive methods, it is acknowledged that when students are involved in inquiry they actually follow the scientific method. They work like scientists by following the five steps that constitute the essential features of inquiry (NRC, 2000; Walker, 2007), described as follows. Firstly, learners are engaged by scientifically oriented questions. In the best of cases these questions should come from the students, even though often they are provided by the teacher. Secondly, learners give priority to evidence, allowing them to develop and evaluate explanations that address these scientifically oriented questions. Here the teacher does not simply provide recipe-like instructions for each experiment; rather learners plan and decide how experiments are to be conducted. Thirdly, learners formulate an explanation from evidence to address scientifically oriented questions. This explanation should refer to the initial question they were trying to answer. Fourthly, once students have made the explanation based on the data they collected, they evaluate it and consider whether it fits into the evidence they already have. Lastly, learners communicate and justify their proposed explanation. Each of these features of inquiry, once applied in a classroom, varies both in terms of the amount of learner self-direction on the one hand and the amount of the teacher's or material direction on the other hand, as presented in the following table (Table 3.3).

Table 3. 3. Essential features of classroom inquiry and their variations

Essential features		Variations		
1.Learner engages in scientifically oriented questions	Learner poses a question	Learner selects from among questions, poses new questions	Learners sharpen or clarify question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learners given data and told how to analyze
3. Learner formulates explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication
<p>More-----Amount of learner self-direction-----Less</p> <p>Less-----Amount of direction from teacher or material-----More</p>				

Source: NRC (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*, p.29.

At first sight it may be believed that these steps follow one another in that order, but in practice it is not the case. Inquiry as a non linear process, phases interact in such a way that at any phase, the decision of revising the original question or for altering data collection procedures may occur. The following chart (Figure 3.4) illustrates this cyclic and iterative process learners get involved in when engaged in inquiry.

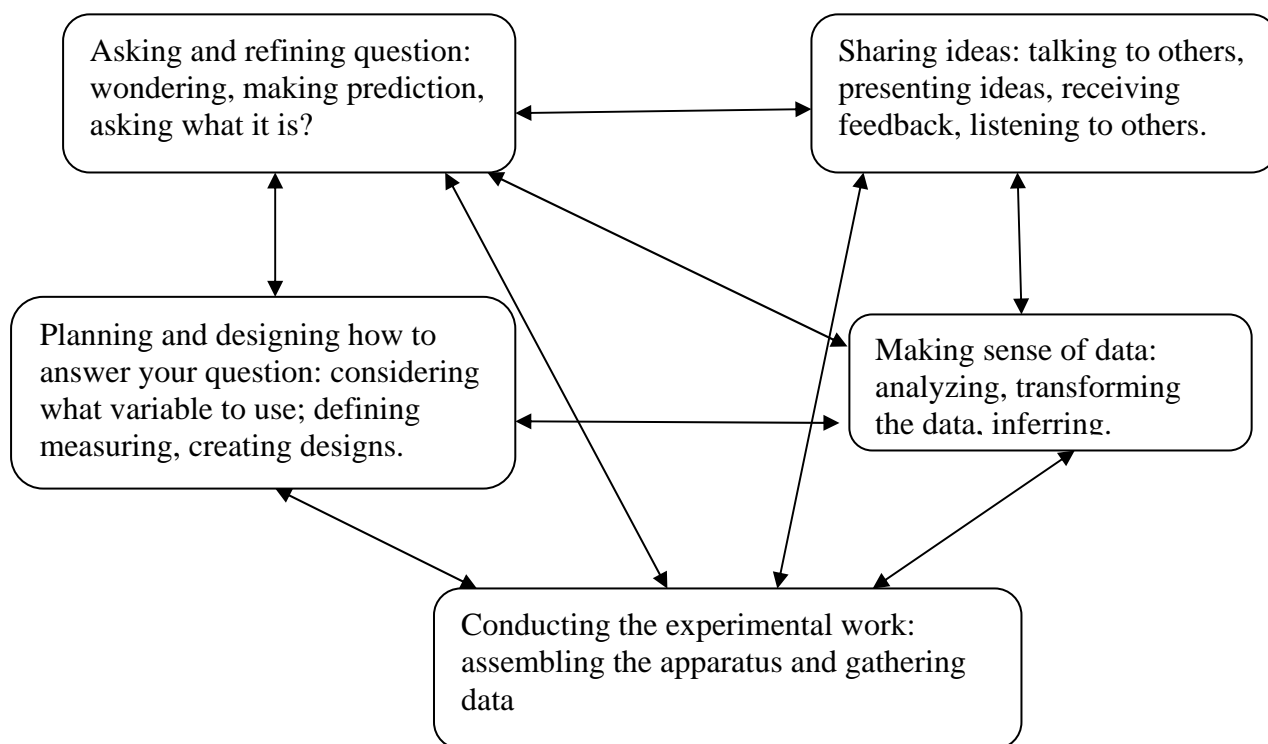


Figure 3. 4. Inquiry cycle (adapted from Krajcik et al., 2000)

In a real science classroom context it is not obvious that one can see a demarcation between phases but it would be more visible when learning activities expand to projects or other similar activities. It is the responsibility of the teacher to direct the whole process and make sure that all learners equally participate at each and every phase of the cycle. As for guidance, teachers need to know when and how and in what form guidance will be useful (Gash, 2009). In brief, it can be agreed that inquiry begins with a question based on observation, which ultimately leads to a conclusion based on evidence through a number of steps including planning, implementing, concluding and reporting (Settlage, 2003).

3.2.2. Teaching and learning science through inquiry

During the second half of the last century until today, a substantial amount of studies has been done and a range of findings in various aspects related to the use of inquiry were widely disseminated. The most common idea shared by both educators and researchers is that modern views about teaching and learning contend that most people learn best through personal experience by connecting new information to what they already believe or know. In

this section, as part of literature review, findings related to the implementation of IBST are presented. They include among others, inquiry in science classroom and how it differ from the so called traditional teaching approaches; the challenges associated with the use of inquiry teaching approach; its successes; reasons preventing teachers from enacting more inquiry in practice as well as ways of dealing with problems associated with IBST.

There is a large body of studies on the use of inquiry in science education. As reported by Anderson (2002), research indicates that ‘inquiry teaching is possible for many teachers but does not show how difficult it is to use it or the percentage of teachers that are able to be successful at it as well as how many are likely to choose adopting it in their daily practices’ (p. 7). Number of findings revealed that understanding what inquiry is especially when it applies to instruction has proven to be challenging for many science teachers (Sutman, Schmuckler & Woodfield, 2008). They pointed out that inquiry-oriented science instruction is seen in a variety of perspectives. Some emphasize the active nature of learner’s involvement associating with hand-on learning and experiential while others link inquiry with discovery approach or with development of process skills associated with the scientific method whose steps were earlier presented. From a science perspective, inquiry-oriented instruction engages students in the investigative nature of science while from the pedagogical perspective; inquiry-oriented teaching is often contrasted with the more traditional expository methods. In its essence, inquiry-oriented teaching engages students in investigation to satisfy curiosity that gets satisfied once individuals have constructed mental framework that adequately explains their experiences (Chen, 2008). As it will be further discussed in the short coming paragraphs that knowledge is constructed, listening to a teacher lecture and reading textbooks are not enough to gain depth of knowledge. Instead, students need to have opportunities to personally construct their own understanding by posing questions, designing and conducting investigations, and analyzing and communicating their findings (Hinrichsen & Jarrett, 1999). By so doing, they take an active role in their learning which the primary tenet of inquiry is all about consisting of a progressive paradigm shift from teacher centred towards learner centred teaching and learning approach.

It was also established that inquiry based approach differs from the traditional teaching approach. The latter is still widely used in many cases despite the talk of change. Layman (1996) argues that the previously dominant view of instruction as direct transfer of

knowledge from teacher to student does not fit the current perspective of teaching and learning. To point out the uniqueness of the new approach compared to traditional one, Audet (2005) identifies the essential features of an inquiry-based classroom including “the engagement in activities that are congruent with the developmental readiness of students, frequent opportunities to ask and answer questions, a gradual but steady movement toward student control over the learning” (p. 14). As an instructional framework based on constructivism, inquiry-based teaching and learning focuses on motivational factors, provides opportunities for social interaction and promotes active learning environments. With this regard, Wilfred (nd) and Hammerman (2006) summarize by providing a list of few, but fundamental aspects in which inquiry based approach differs from a more traditional teaching approach in the following table (Table 3.4).

Table 3. 4. Differences between inquiry-based and traditional teaching approaches

Aspects in teaching & learning	Inquiry based approach	Traditional approach
Principle learning theory	Constructivism	Behaviourism
Student participation	Active learner	Passive/ receiver/ listener
Student involvement in outcomes	Increased responsibility	Decreased responsibility
Student’s role	Problem solver	Direction follower
Student’s work	Varied	Prescribed
Teacher’s role	Guide/ Facilitator	Director/ Transmitter
Curriculum goals	Process oriented	Product oriented

The difference between inquiry and non-inquiry forms of science has also been investigated. This is very crucial for teachers like those participating in this study because sometimes they might believe that they are involved in inquiry teaching just because their learners are doing investigations while inquiry-based activity differs fundamentally from non-inquiry based activity. Walker (2007) raises the issue of concern with this view as follows:

Simply by having students do experiments does not mean they are engaged in inquiry-based science. In a typical non-inquiry lesson the teacher would explain the important points of the topic being learnt, and then the students would be given an experiment to do to reinforce this knowledge. (p. 9)

From the above description, it should be mentioned that the purpose of inquiry instruction is not to supplant the teaching of content. As pointed out by Sutman, Schmuckler and Woodfield (2008), “by encouraging an experiential understanding of scientific concepts, it serves to deepen understanding making the content more memorable and meaningful to

students” (p. xi). However, it may be clarified that inquiry activities should not necessarily be incorporated into each and every lesson for students to benefit. Instead, such activities can be used into lessons selectively and are ideally suitable for introducing important new science idea and conceptual understanding.

An inquiry classroom, instead of being a scene of “a Teacher-Master and Learners-Subjects” it is rather two way reciprocal interactional setting between the teacher and learners. Describing the interactional relationship between students and the teacher in an inquiry classroom, Hinrichsen and Jarrett (1999) argue that when inquiry is implemented systematically in the classroom, the students take increased control of their own learning through the guidance of the teacher. This guided self-control enables students to “ask questions and seek meaningful solutions, to design and conduct hand-on investigation, to think critically and reflect on their prior misconceptions” (p. 6).

The view about how learners’ control of their learning when engaged in inquiry is not something agreed upon by all. In fact the teacher’s guidance towards students own control of their learning is differently viewed with two tenancies; one advocates an unguided or minimum guidance and while the other supports a strong and direct guidance (Kirschner, Sweller & Clark, 2006). Both tenancies emphasize different features but the strategy of “minimum guidance” seems to be the less recommendable as evidenced by the following:

Even students with considerable prior knowledge, strong guidance while learning is most often found to be equally effective as unguided approach. Not only is unguided instruction normally less effective, there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge. (p. 83-84)

For inquiry-based instruction to be effective in science classroom, it should fit into a broader view of inquiry alongside a continuum of inquiry. Such a continuum considers both the degree of guidance in inquiry and the degree of inquiry where the former ranges from the guided to the open-ended inquiry while the latter ranges from the full to the partial inquiry (Brown, Abell, Demir & Schmidt, 2006). Similarly, but in a more detailed way, Wenning (2005a) has proposed a more comprehensive continuum along which move, in reversing directions, what he terms the intellectual sophistication and the locus of control as respectively describing the levels of inquiry and the associated guidance.

In this study, I intended to interpret inquiry-based instruction using Wenning's (2005a) range of teaching practices where the locus of control compared to the degree of guidance in inquiry shifts from the teacher to the learner while the intellectual sophistication compared to the degree of inquiry increases continuously from discovery learning to hypothetical inquiry at the highest level through other sub-levels including, in this order, 'interactive demonstration, inquiry lesson and inquiry laboratory' (p. 7). In a more detailed description that expands the continuum, laboratory activities are sub-divided into guided, bounded and free inquiry laboratory on one hand and both pure and applied hypothetical inquiry on another hand. The following graphical representation (Figure 3.5) illustrates this variation over the continuum.

Discovery learning	Interactive demonstration	Inquiry lesson	Guided inquiry lab	Bounded inquiry lab	Free inquiry lab	Pure hypothetical inquiry Applied hypothetical inquiry
Low			Intellectual sophistication			High
Teacher			Locus of control			Student

Figure 3. 5. Hierarchy of inquiry-oriented science teaching practices (From Wenning, 2005b, p. 10)

Furthermore, Wenning (2011) provides more details about this inquiry spectrum and indicates a range of intellectual and scientific process skills learners develop when taught through inquiry. He further provides useful guidelines as to what both learners and teachers are involved in within each level of inquiry (pp. 12-13). In its very simplest form, the degree to which teachers structure learners' activities is sometimes referred to as "guided" versus "open" inquiry where the more responsibility learners have for asking and answering questions, designing and carrying out investigations, and communicating their results, the more open the inquiry, and the more responsibility the teacher takes, the more guided the inquiry.

Empirical studies indicate that inquiry-based instruction can be described in terms of a number of characteristics shared by teachers adopting this approach. It is important to note that these characteristics apply not just to science classrooms but to all classrooms. Layman (1996, pp. 34-35) presented these characteristics in terms of actions that teachers go through, which include to:

1. encourage and accept student autonomy and initiative;

2. use raw data and primary sources, along with manipulative, interactive, and physical materials;
3. when framing tasks, use cognitive terminology such as classify, analyse, predict, and create;
4. allow student responses to drive lessons, shift instructional strategies, and alter content;
5. familiarize themselves with students' understandings of concepts before sharing their own understandings of those concepts;
6. encourage students to engage in dialogue, both with the teacher and one another;
7. encourage student inquiry by posing thoughtful, open-ended questions and asking students to question each other;
8. seek elaboration of students' initial responses;
9. engage students in experiences that pose contradictions to their initial hypotheses and then encourage discussion;
10. allow time after posing questions;
11. provide time for students to construct relationships and create metaphors; and
12. nurture students' natural curiosity.

As it can be seen, Laymans' characteristics are very similar to those presented by Martin (see pp. 40 - 41) showing that constructivist ideas underpin the inquiry classroom. The same author further adds to these two other important points, which are the teachers' role and their interactive relationship with students. He highlighted a shift of role in the sense that when students take the role of active learners, the teacher's role changes from dispenser of knowledge to facilitator of learning. Thus, teachers acting as facilitators of learning create the environment in which investigations take place. By so doing "they impart conceptual knowledge, mathematical and technical tools, and general guidelines at optimal moments, and at the same time they select learning experiences that they adapt to meet the interests, knowledge, abilities and backgrounds of their students" (Layman, 1996, p. 36).

Several advantages to utilizing inquiry-based instruction (Oates, 2002) have been noted, and inquiry science has also provided great benefits in diverse classrooms (Songer, Lee & McDonald, 2003). Furthermore, most researchers in science classroom inquiry who focused on inquiry as a teaching approach noted that it has provided positive results (Anderson, 2002). For example, Walker (2007) noted two main advantages of teaching science through inquiry: firstly, inquiry-based methods of teaching improved student achievement, and secondly they had positive effect on students' attitudes towards science,

with students engaged in inquiry-oriented work finding science more exciting. Furthermore, Marsha (2000) also noted that inquiry-based learning has been shown to have a positive impact on both student content understanding and skills acquisition. Further, it fosters skills that help students to prioritize information, deciding which is most important and which least helpful. As mandated by many state science curriculum standards, such as the NSES in the USA, it was introduced in Rwanda with the firm conviction that it would bring positive results and change the then existing status of science and learning.

Many other researchers have displayed converging viewpoints towards the advantages and benefits offered by use of IBST and learning (Cavicchi & Hughes-McDonnell, 2001; Chin & Kayalvizhi, 2002; Davis & Irwin, 2001; Leonard & Penick, 2000; Linn, 2000; Melear, 2000; Singer, 2003; Winning, 2005a). For example, Chin and Kayalvizhi (2002) argue that the use of teaching through inquiry in the classroom provides students with opportunities that stimulate high-order thinking, which in turn “let them carry out their own investigations especially open-ended investigations, where students pose the problem to be investigated and design their own procedures to answer the questions” (p. 269). Furthermore, the NRC (2000) recently reviewed a significant amount of research and highlighted the effectiveness of constructing intellectual understanding through inquiry as the best way of getting learners to learn content knowledge effectively, a wide array of intellectual process skills, and appropriate scientific dispositions.

Moreover, there is a range of other positive values that IBST and learning promote in students, such as curiosity, enthusiasm and confidence. For example, Davis and Irwin (2001) reported that “students engaged in scientific inquiry appreciate the nature of science methodology, become actively engaged and gain confidence in their ability to become independent learners” (p. 5). To reinforce these ideas about the advantages of inquiry-based instruction, Colburn (2000) describes it as being “equal or superior to other instructional modes and results in higher score on content achievement tests” (p. 44). Over and above all this, besides being most commonly associated with science, inquiry-based teaching is relevant for any field of learning.

Although this teaching approach has been shown to have several advantages, the traditional science teaching approach still prevails in many instances, where teachers are still focusing on accumulation of facts through memorization. Wee, Shepardon, Fast and Harbor

(2007) report that “even when inquiry is included in the science curriculum, it is often viewed as a body of knowledge rather than a process in which a better understanding of the world can be obtained” (p. 63). Furthermore, it is widely experienced in many poor countries that “even though inquiry-based science is the buzz these days, many curriculum materials are still based on traditional approaches and fail to engage students in inquiry” (Volkman & Abell, 2003, p. 38). Consequently, despite the talk of change, it seems as if very little has changed in the way science is taught, where teacher talk and textbooks are still the primary providers of science information to students. Therefore inquiry-based science has not yet become a prominent part of science teaching in many developing countries, including Rwanda, where it is at its earlier stage of implementation, partially justifying the need to conduct this study. In the case of Rwanda (as in many other developing countries, such as Zimbabwe and Benin (Gado, 2005)), Earnest and Treagust (2004) noted pessimistically that the availability of laboratory equipment might not change their style of teaching because of overcrowded classes, infrequency of practical lessons, and lack of physical space in schools.

Researchers have investigated the reasons why inquiry science has not been widely implemented despite the advantages it claims to bring to teaching and learning. Costenson and Lawson’s (1995) findings, although a bit outdated, still constitute the main impediments that teachers repeatedly evoke as reasons for not regularly implementing inquiry in their daily practices. These impediments include the time and energy required to produce high-quality inquiry lessons; time required to teach through inquiry; reading difficulty associated with translating existing textbook knowledge into active inquiry; lack of administrative support; learners’ immaturity to cope with inquiry requirements; teachers’ habits; textbooks; discomfort at not being in control of the lesson; and lack or shortage of relevant materials for hands-on learning. Eltinge and Robert (1993) further pointed out three major reasons for not regularly implementing inquiry which seem to apply in the Rwandan educational context considering the current teaching and learning environment:

1. Science teaching standards issued by state agencies are generally more content-oriented than process-oriented, with the focus on the mastery of the body of information and little emphasis on the process of inquiry as a method of learning science knowledge;
2. When student learn science through inquiry, they learn less factual science information but achieve a greater depth of understanding of that information. However, it is much easier to assess the effectiveness of student learning of science as

a body of factual information than to assess the effectiveness of their science learning through inquiry; and

3. Science textbooks tend to present science more as a body of information than as a method of inquiry, and as a result science instruction in schools continues to be textbook- driven.

Besides these three reasons, many other factors have been identified as being at the origin of not using inquiry-based science instruction properly, which are surprisingly persistent over time. For example, Welch, Klopfer, Aikenhead and Robinson (1981) pointed out reasons that included (a) lack of time, (b) lack of training, (c) lack of materials, (d) lack of support, (e) overemphasis on assessing content rather than process learning, and (f) inquiry being too difficult. About two decades later Bybee (2000) also reported three reasons, describing scientific inquiry as being time-consuming, too expensive, and simply too advanced for learners. Recently Ackay's (2007) study revealed similar problems that prevent teachers from better implementing inquiry teaching, such as (a) a major gap between teachers' knowledge and what they actually do in practice, (b) insufficient experience with inquiry teaching and learning approaches, (c) unfamiliarity of students with participating as partners in inquiry, (d) resistance of some students to working on their own inquiries, and (e) management issues. For Wee, Shepardon, Fast and Harbor (2007) the teachers' ability to implement inquiry-based lessons is hampered by lack of pedagogical training for using inquiry techniques. In the experience of Rwanda this is an unfortunate reality, as few teachers are prepared adequately to facilitate inquiry in the classroom. In this regard Audet and Jordan (2003) argue that:

Few teachers have experienced science learning through inquiry as students or during their pre-service or in-service preparation; thus they have few pedagogical models or predispositions toward inquiry upon which to draw. They tend to teach the way they were taught - through lectures, demonstrations, and other didactic teacher-centered approaches. (p. 230)

More recent studies, like those of Anderson (2003, 2007) and Windschitl (2004), also acknowledge that most teachers have very little experience with inquiry in a formal scientific sense, and as a consequence display a very naïve and informal conception of inquiry in the classroom. A review of selected science education research in Africa suggested a number of factors hindering the teaching and learning of science in schools. For example, you may find

some science teachers claiming that they teach using inquiry methods, but when asked to provide details of their enactment of inquiry they often come up with an array of diverse and possibly contradictory examples, showing that even science educators themselves do not have a shared understanding of science inquiry teaching methods (Kerlin, McDonald & Kelly, 2009). Consequently, many teachers feel that they are inadequately prepared to use inquiry-based learning in the classroom (Colburn, 2000), and therefore fear that a student's answer to an inquiry-based problem will not be "direct or straightforward and may lie outside the teacher's sphere of knowledge" and thus the teachers "have to be comfortable with the ideas of their learners asking questions for which they might not know the answers" (Chin & Kayalvizhi, 2002, p. 271).

To circumvent these problems, there is a need for a supportive environment for inquiry-based teaching and learning in all of its dimensions, being ongoing or tailored to meet the changing needs of the science staff and their teaching (NRC, 2000). These changes shouldn't concern just the teachers but all involved stakeholders, including students, parents and administrators as well as all other subjects. Such support for inquiry-based teaching and learning should encompass different aspects including: (a) understanding what is meant by inquiry-based teaching and learning and knowing the advantages documented for inquiry by research; (b) understanding the change process that occurs when teachers are learning to teach through inquiry and students are learning to learn through inquiry, so that all of their concerns can be anticipated and support tailored to meet their evolving needs; and (c) providing a coordinated support system that maximizes staff's opportunity to grow and succeed in teaching through inquiry (NRC, 2000, p. 143).

For this growth to take place, teachers should be provided with opportunities and be encouraged to participate in professional development programmes that serve to enhance their understanding of scientific inquiry and provide learning opportunities related to use of inquiry in the classroom. In fact, "there is evidence that professional development programs do provide experiences that help teachers develop their overall knowledge about inquiry, in particular, the ability to develop a more acute vision of inquiry-based application in classroom" (Wee et al., 2007, p. 83). Besides these teacher professional development programmes, there are what Audet and Jordan (2003) refer to as "Informal Education Institutions such as science museums, zoos, aquariums which present inquiry experiences to

the public and are particularly well suited to serve as centres of teacher professional development” (p. 235). Unfortunately, in Rwanda this suggested alternative way is still far from a possibility since adequate science teachers’ professional development programmes are not yet available, and there are also none of the informal institutions mentioned above. As a consequence many teachers do not exhibit much expertise of inquiry in their science classroom in the Rwandan context.

In the new Rwandan O-level science curriculum inquiry is envisaged as an investigative aspect and is described in terms of the general objectives of teaching each of the three science subjects, namely biology, chemistry and physics. In each of these three subjects students are expected to be able to observe phenomena, perform research, experiment, analyse results and draw accurate conclusions from experiments, and therefore must move from knowledge of direct experience to a level of scientific ideas (MINEDUC, 2007b). The curriculum suggests teaching and learning activities that include experiments and practical demonstrations carried out by learners under the teacher’s guidance in order to reinforce learning. The three science subjects have a similar general orientation, with some variations specific to each one. For example, in this new O-level science curriculum biology is based on a discovery methodology requiring practical exercises and various activities to be carried out while learning each topic, leading learners to discover facts about nature and humans by observation and experimentation (MINEDUC, 2007b). Active group methodology is greatly recommended as long as it favours the discovery of positive information through communication and cooperation. In chemistry the curriculum suggests that the teaching must encourage learners to think, ask and answer questions in a way that satisfies their curiosity about natural phenomena by observing and experimenting. It reorients chemistry teaching towards stimulated and guided observation through the direct experiences of learners and stresses the practical aspects, which allows learners to gain knowledge in the handling of chemicals and laboratory equipment in order to adopt a positive attitude towards science in general and chemistry in particular. In physics teaching methods are to be learner-centred and primarily active, inductive and practical. The teacher is supposed to create learning situations that need observation of facts and phenomena in everyday life or use of technology and professional techniques to develop a spirit of curiosity, interest and critical thinking in learners (MINEDUC, 2007b).

To sum up, I share the idea of Jordan (2005), who argues that even though inquiry may not be the only way of teaching science, many educators believe it may be the best way for students to learn science. The same view was highlighted in the NSES, highlighting that “students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry” (NRC, 1996, p. 105). Acknowledging that there is no a single model of IBST and learning to be followed, various factors such as the topic, the teacher, age and stage of development of learners as well as resources available may impact on its implementation. However, there are some widely recognised features of activities of both teachers and learners that are indicative of inquiry teaching and learning. Even though they do not necessarily take place simultaneously in each and every inquiry-based lesson, over time learners get involved in the following activities when learning science through inquiry (Inter Academy Panel, [IAP], 2010, p. 9):

1. observing and, where possible, handling and manipulating real objects;
2. pursuing questions which they have identified as their own, even if introduced by the teacher;
3. taking part in planning investigations with appropriate controls to answer specific questions;
4. using and developing skills in gathering data directly by observation or measurement and by using secondary sources;
5. using and developing skills in organizing and interpreting data, reasoning, proposing explanations, and making predictions based on what they think or find out;
6. working collaboratively with others, communicating their own ideas and considering others’ ideas;
7. expressing themselves using appropriate scientific terms and representations in writing and speaking;
8. engaging in lively public discussions in defence of their work and explanations;
9. applying their learning in real-life contexts; and
10. reflecting self-critically about the processes and outcomes of their inquiries.

As for the teachers, they provide learners with opportunities and support to facilitate learning that include the following (IAP, 2010, p. 10):

1. asking questions that require reasoning, explanations and reflection, and showing interest in the students’ answers;

2. providing an opportunity for students to encounter materials and phenomena to explore or investigate at first-hand;
3. arranging for discussion of procedures and outcomes as well as practical investigations in small groups;
4. encouraging through example tolerance, mutual respect and objectivity in small group and whole class discussions;
5. providing access to alternative procedures and ideas through discussion, reference to books, resources such as the Internet and other sources of help;
6. setting challenging tasks while providing support (scaffolding), so that students can experience operating at a more advanced level;
7. teaching the techniques needed for advancing skills, including the safe use of equipment, measuring instruments and procedures;
8. encouraging students through comment and questioning to check that their ideas are consistent with the evidence available;
9. helping students to record their observations and other information in ways that support systematic working and review, including using conventional representations; and
10. encouraging critical reflection on how they have learned and how this can be applied in future learning.

During this reciprocal interaction what the student acquires is not only content knowledge but a number of skills, including how to: approach a problem, identify important resources, design and carry out hands-on investigations, analyse and interpret data and, perhaps most importantly, recognize when they have answered the question or solved the problem (Marsha, 2000). It is through the interactive actions of teachers and learners that one can assess the extent to which a minimum of inquiry teaching and learning is taking place. In reality all those actions do not occur simultaneously, but may describe a typical inquiry-based science classroom. In the most ideal situation of a true inquiry (rather than learning about inquiry) students learn through inquiry by applying the process of inquiry to problems, devising ways to obtain and analyse data, and discussing the meaning of their data and experiences, and end up by communicating their findings and ideas with others (Leonard & Penick, 2009).

3.3. TEACHER CHANGE WITH CURRICULUM REFORM

Any change that is brought into the curriculum requires teachers also to change in order to fit into the new associated requirements; once it is about inquiry, teachers are acknowledged to play a critical role in achieving a desired state consistent with inquiry. Their effectiveness is mapped as valuing inquiry, encouraging an inquiry orientation in others and possessing skills in enabling others to understand inquiry as a way of knowing (Welch, Klopfer, Aikenhead & Robinson, 1981). However, this change towards inquiry poses numerous challenges for teachers, who find a pedagogy based on inquiry difficult at first, even though they end up expressing considerable satisfaction in seeing their students motivated to learn, becoming proficient at asking questions and devising ways of answering them, and demonstrating deep understanding of scientific concepts as a result of teaching and learning through inquiry (Krajcik, Blumenfeld, Marx & Soloway, 2000). With this regard, Khan (2009) pointed out three basic requirements for teachers to effectively embrace and implement inquiry teaching strategies, and to acquire them necessitates a substantial change in the teacher. These requirements are that teachers must understand the nature of scientific inquiry, have sufficient understanding of the structure of their particular discipline, and be skilled in inquiry teaching techniques.

In the case of Rwanda, the revision of the science curriculum for O level gives priority to a methodological approach that is student-centred, with emphasis on inquiry-based activities as well as on achieving education objectives and systematic treatment of content through learning-teaching activities. The science teachers' responses to the challenge of changing their practices to adapt new changes brought into the O-level science curriculum in Rwanda is at the core of the present study. In this section issues including theories of change, the teachers' role in implementing the curriculum and factors associated with teacher change with curriculum reform are discussed. However, before discussing these issues of interest it is important clearly to understand the meaning of change and circumstances under which it occurs, with particular focus of course on educational change.

Fullan (2007) acknowledges the double dimension of educational change as being "technically simple and socially complex" (p. 84). He suggests that its purpose is to help schools accomplish their goals more effectively by replacing some structures, programmes and/or practices with better ones. This dichotomy of educational change applies in many

aspects. It can, for example, be voluntary or imposed, sought or resisted, can happen by chance or be designed, and can have both subjective and objective components in its meaning. In any case, whether looked at from the standpoint of reformers or those they manipulate, of individuals or institutions, whether desired or not, “a real change represents a serious personal and collective experience characterized by an ambivalence and uncertainty; and if the change works out, it can result in the sense of mastery, accomplishment, and professional growth” (Fullan, 2007, p. 23).

Above all, educational change is a dynamic process that involves interacting variables over time. As pointed out by Fullan (2007), the difficulty in its implementation is that educational change is not a single entity – rather it is multidimensional. In implementing any new programme or policy in education at least the three following dimensions are to be considered (Fullan, 2007, p. 30): (a) the possible use of new or revised materials such as curriculum materials or technologies; (b) the possible use of new teaching approaches, including new teaching strategies or activities; and (c) the possible alteration of beliefs, including particular new policies or programmes. These three dimensions are essential for the intended outcome to be achieved.

In the forthcoming sub-sections some theories of change are discussed. Curriculum change and factors influencing its implementation are also discussed, all leading to an understanding of teacher change with regard to implementing IBST.

3.3.1. Theories of change

To understand the relationship prevailing when teachers change as a result of curriculum reform, it is worth briefly discussing some theories of change. There are many, so the discussion focuses only on those that apply to educational change, serving to interpret the changes experienced by science teachers involved in the present study in response to the curriculum reform. They are also considered since they were developed with regard to changes in the workplace setting, and are therefore relevant to teachers when they respond to changes occurring in the curriculum and within their schools as workplaces. These theories include (a) traditional change theory (Chin & Benne, 1969), (b) adaptive change theory (Heifetz, 1994), and (c) advanced change theory Hooijberg, Hunt & Dodge, 1997). A fourth

one, namely the theory in action and double-loop learning (Argyris, 1996), is added since it can refer to the gap between the intended and implemented curriculum.

The traditional change theory refers to two strategies, one known as empirical-rational, assuming that people will be more likely to change if they understand the logic for change and see themselves as benefiting from it, and another called power-coercive, consisting of forcing people to change, including use of external sanctions from political and economic power in most cases. The former applies better to teachers implementing a new curriculum, but its success would depend on the extent to which they were involved in the process of revision. The adaptive change theory stipulates that adaptive change can only take place using a strategy of mobilizing people to revise their attitudes, work habits and lives. For teachers to adaptively change, this strategy seems to be inefficient unless appropriate measures such as teacher professional development programmes are considered. The advanced change theory, which is more complex than the first two, requires the leader to employ a high level of cognitive, behavioural and moral complexity leading to change of both the leader and the followers. In the context of the present study, curriculum designers or developers and teachers implementing a new or revised curriculum both seem to be subject to change. Lastly, the theory in action and double-loop learning consider the espoused theory of action and the theory in use, referring respectively to the way people say they behave and the way in which they actually behave. This may be understood with regard to the gap existing between the intended and the implemented curriculum, where teachers may claim to implement IBST while they do not really do so in practice. Figure 3.6 presents a concept map of the four theories of change described above.

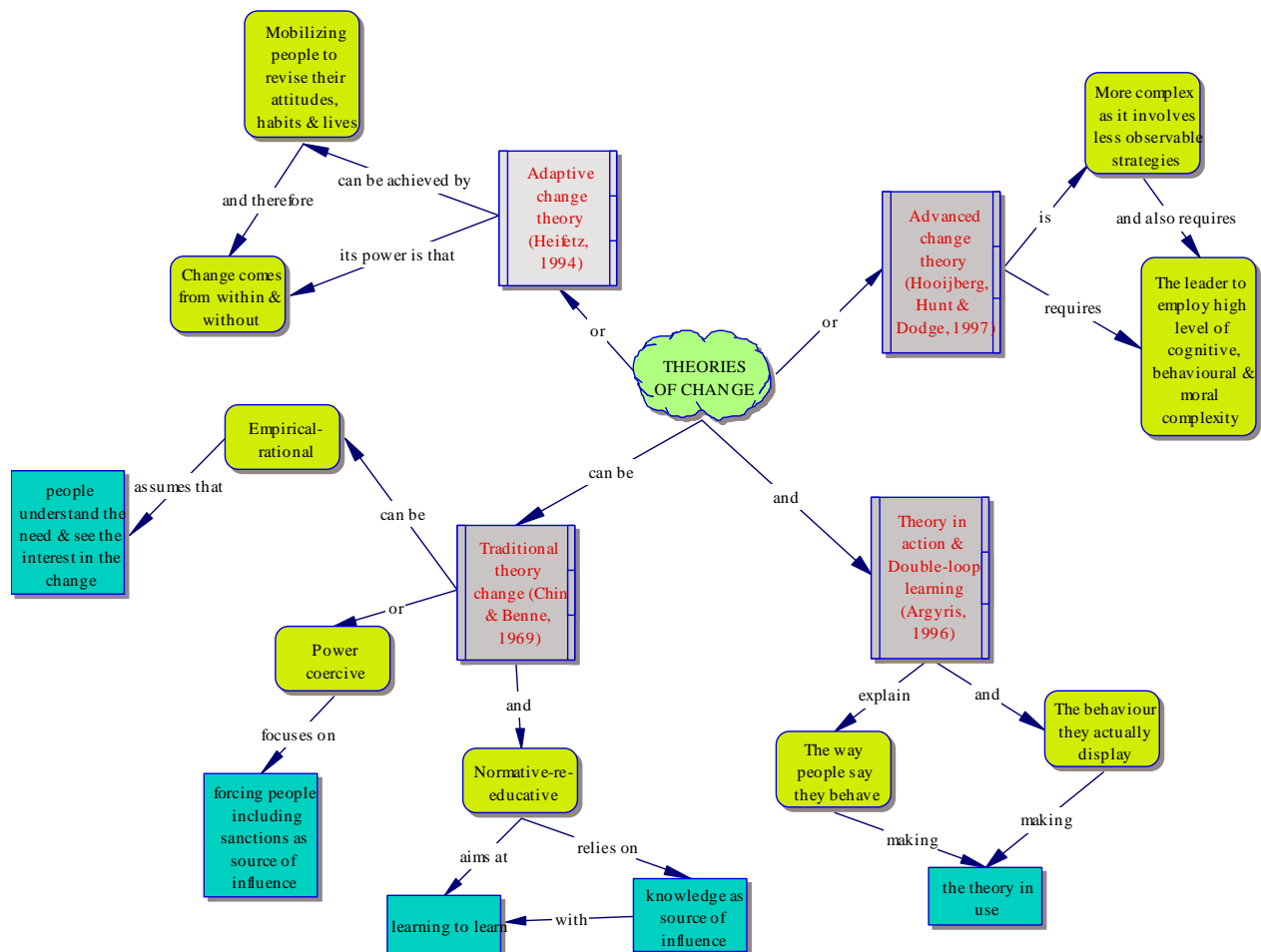


Figure 3. 6. Concept map of the four theories of change described in this study.

Despite this variety of theories of change, it seems that the traditional model of thinking about educational change no longer provides sufficient conceptual tools for responding to the current multidimensional needs and politically contested environment (Sahlberg, 2003). Therefore both theorists and practitioners acknowledge that significant educational change cannot be achieved by a linear recipe-like process. Emerging new theories of educational change are thus beginning to be considered. Among others, those mostly referred to currently are those related to ideas derived from the sciences of chaos and complexity, whose characteristics are (a) the non-linearity of process, (b) thinking about education as an open system, (c) the interdependency of the various components of the system, and (d) the influence of context on the change process itself (Sahlberg, 2003).

Description of these theories of change in this study is based on the assumption held by the researcher that teachers do not respond in the same way to change, through not having the same background or experiences, or simply because they are themselves different. Therefore, for the purposes of this study the empirical-rational strategy in traditional change theory and adaptive change theory will be used when trying to understand teachers responding to the new requirements resulting from the curriculum revision introducing an inquiry teaching approach.

3.3.2. Curriculum change

“The ability of schools to remain vital and important institutions depends on their ability to understand and cope with the changing world around them” (Levin & Riffel, 2000, p. 178).

There is a general trend of developing new curricula across the globe, especially in emerging nations; these curricula are well designed, and the aims that they intended to achieve are laudable (Rogan & Grayson, 2003). Having some historical and political similarities, South Africa and Rwanda are no exception, considering the number of curriculum reforms and revisions they have experienced since 1994. Kennedy (1996) makes the point that many countries, especially the developing ones, are nowadays exposed to sociopolitico-economic changes, with governments increasingly concerned to produce citizens who will be able to respond positively to a new environment, who can adapt, change and learn new skills at different points in their lives, and who will contribute to the society which they wish to develop in the future. Although Kennedy’s article is dated more than a decade ago, his statements are still relevant:

We are experiencing a period of expansion and change in many public educational systems throughout the world, as governments try to implement the sort of educational programmes they think will achieve their aims but within the resources available to them. The change is represented by increased access to education at all levels, and a consequent re-thinking of the aims, objectives, and manner of delivering of the curriculum. (p. 77)

However, when it comes to implementation of change within the existing system, there needs to be great awareness of the inherent complexity. Fullan (1993) argues that educational change is technically simple but socially complex. He points out many difficulties, including those related to planning and coordinating as components of a multilevel change process. He describes implementation as consisting of the process of putting into practice an idea, programme, or a set of activities and structures new to people attempting or expected to change. Among those people subject to this change are teachers, who play an essential role in the change process and therefore in curriculum implementation.

To better understand the nature of curriculum change and the way it impacts on teachers' practices, it is important to first remind ourselves of a number of underlying assumptions about curriculum change (Ridden, 1991), as well as the types of curriculum representations in order to be specific about which is referred to in this study. Firstly, curriculum change is not easy for it requires changing people and therefore requires readiness. Secondly, curriculum change is a process and not a single event, and therefore requires ongoing support. Lastly, curriculum change is unique and influenced by many factors. As for the various curriculum representations, they include the intended curriculum, which is the basic philosophy of the curriculum as elaborated in a curriculum document; the implemented curriculum, which is the actual instructional process in the classroom, often referred to as the curriculum-in-action; and the achieved curriculum, which are the resulting outcomes of students (Earnest, 2003, p. 53).

A quasi-similar illustration of the evolution of curriculum is Van den Akker's (1990) adaptation, that includes: (a) the ideal curriculum at a macro or system level translating the curriculum designers' intentions; (b) the formal curriculum which takes the form of a written curriculum or curriculum document; (c) the perceived curriculum made up by the users' interpretations; (d) the operational curriculum; (e) the experienced curriculum; and (f) the attained curriculum. In this study all teachers' responses reflect the way in which these teachers actually implement the intended curriculum. Therefore the study is about the implemented curriculum, and does not attempt any analysis of intended or achieved ones.

Regarding the curriculum change hierarchy, Wideen and Pye (1994) identified three different types according to the level and associated difficulty of implementation. At the very lowest level there are small changes easily assimilated within teachers' former practices. The

following level consists of more substantial changes that require overcoming teachers' prior beliefs. Lastly, the more complex changes require a conceptual shift in the way teachers think about teaching. Considering the teacher's involvement in each and every type of curriculum change, it appears clear that teachers are the critical agents of bringing about changes in their classrooms. Thus, they should be the major focus of analysis and source of evidence regarding the introduction of curriculum reform and its implementation. In this regard Anthony (2008) emphasizes the important role of teachers in implementing a curriculum, arguing that:

Curriculum starts as a plan. It only becomes a reality when teachers implement it with real students in a real classroom. Careful planning and development are obviously important, but they count for nothing unless teachers are aware of the product and have the skills to implement the curriculum in their classroom. (p. 77)

Similarly, Fullan (1993) went on to acknowledge this crucial role of teachers, arguing that it is one thing to create a new curriculum but you cannot assume that teachers will be enthusiastic about using it despite being the key agents in its implementation. This is probably due to humans being inherently resistant to change. Thus, it is important to note that identifying teachers' concerns is essential for successful curriculum implementation (Cheung, Ng & Hattie, 2000).

Although in the case of Rwanda the NCDC made use of experienced teachers in the design and development of the new science curriculum, the potential means of upgrading under- and unqualified teachers, who have to implement it within a context of lack of materials and relevant textbooks, is still limited. Fullan (2001) suggests that effective educational change cannot happen until an improvement in teachers' conditions occurs. However, it has been pointed out that the potential problem lies in the fact that teachers are sometimes asked to give more than they have. For example, they will not only be asked to change their practices, but also to change previously held attitudes and beliefs, regardless of the subsequent preparation not always being available (Kennedy, 1996). What is mostly required is a mutual collaboration of all educational stakeholders, as emphasized by Bailey (2000), arguing that "so much more could be done if researchers, policymakers and administration worked with teachers rather than on them" (p. 113). This can be translated into reality through various forms of support to teachers, mostly known as teacher professional development programmes.

The kind of support required refers to the new curriculum itself on the one hand, and to the teachers' role within the new curriculum on the other. This implies knowledge about the approach and the design of the new curriculum, as well as how they are expected to manage it. For this to take place and to be effective, both pre-service and in-service training as well as physical resources to implement the change are required. It is only when teachers come to understand the reality of educational change in the context of their classroom that they will actually be able to implement change (Earnest, 2003).

3.3.3. Factors involved in curriculum change implementation

Designing is one thing, and implementing quite another. This also applies in science education, where too often the focus of curriculum change initiatives seems to be limited to the development of science curricula, while the details of how they will be implemented at school level are neglected (Rogan & Grayson, 2003). Curriculum change and therefore its implementation involve many factors, and require that teachers' beliefs, views and behaviours be taken into account. For example in the case of South Africa with the change consisting of the implementation of C2005, Rogan and Grayson have adapted the Sergiovanni's (1998, p. 579) six proposed forces of change and noted that the use of different change forces can only have their impact in specific circumstances. The adaptation made by Rogan and Grayson (2003) highlighted five following types of change forces which differ by their potential effects and likely endurance. These are (p. 1178):

- *Bureaucratic changes forces* whose changes rely on mandates, policy documents, standardised outcomes, direct outside supervision, external assessment and other prescriptive methods;
- *Personality/ leadership change forces* whose changes rely predominantly on the vision, drive and interpersonal skills of a strong and/or charismatic leader;
- *Market driven change forces* whose changes rely on market forces to provide incentive and motivation to change;
- *Professional change forces* whose changes rely a sense of professionalism that embrace code of conduct and standards of teaching and learning; and

- *Learning community based change forces* whose changes rely on shared cultural values and goals regarding teaching and learning and a commitment to put them into practice for the common goal.

The respective consequences and endurance associated with these change forces range from a merely superficial change where the teacher may just change to avoid sanctions to a more substantive change that can reshape the whole learning community in a most sustainable way.

Furthermore, there are also wider issues taking place, such as the working conditions and contexts where curriculum change is to be implemented. Ekiz (2004) argues that “working conditions and contexts is the crucial theme in any consideration of any change because it is in these that change is experienced, realized and mediated” (p. 242). Fullan (2007, p. 87) lists nine key factors that enter into account in the implementation process, grouped into three categories to explain each of them and their interconnections:

1. Factors related to characteristics of change, including the need, the clarity, the complexity and the quality/practicality;
2. Factors linked to the local characteristics, such as districts, community, principal and teachers; and
3. External factors influencing the implementation, such as Government and other agencies.

The interactive relationship between these factors is represented in the following Figure 3.7.

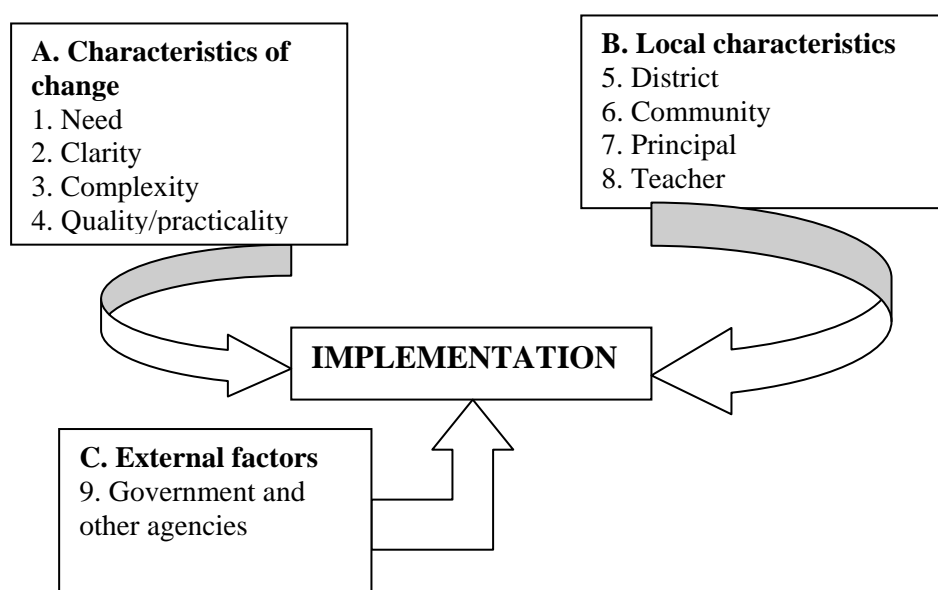


Figure 3. 7. Interactive factors affecting curriculum implementation (adapted from Fullan, 2007)

Teachers' responses to introduction of inquiry-based teaching into the science curriculum would, to some extent, be influenced (though at different levels) by these factors. These factors that constrain and influence the implementation of inquiry-based teaching will be one of the foci of the research, and will need to be understood in the light of the literature dealing with science teacher change. In this study the above mentioned Rogan and Grayson's adaptation will be used to analyse and thus to interpret teachers' views on the general implementation of the new science curriculum, with particular reference to IBST and learning. It is through this understanding that an attempt will be made to interpret teachers' views of what should be done for a better implementation of the new curriculum.

3.3.4. Teacher change

The individuals who primarily implement any educational change are teachers. For that, they have to adopt new ideologies and implement them through their teaching. When a change represents an important shift in both beliefs and practices, it can threaten successful implementation unless necessary professional conditions are met. Talking about the relationship between teachers' change and curriculum reform, Yin and Li (2007) note the following:

The teachers' change is closely related to curriculum reform, which is the inner motive for the success of curriculum reform. However, there are two tendencies; one of resistance and another of voluntary change that teachers will show towards curriculum reform making teachers' change paradoxical. (p. 23)

In the context of the present study, despite the inherent resistance to change little is known about teachers resisting change if it is not just incapacity to implement the change for various reasons. They might, for example, claim to be implementing IBST while this is not actually the case.

However, it is acknowledged that many proposed changes are viewed and experienced as threats to an existing culture, and may be resisted for that reason alone. For example, in the case of South Africa which experienced curriculum reform after apartheid, there was resistance to change from the old curriculum towards the C2005 (Pillay, 2005), although the latter was aiming to improve the political and social aspirations of all South

Africans. Being a phenomenon that can resist even when it does not embed any negative aspects, teachers' change appears to be a multi-dimensional and multi-stage course with complicated interactions among each dimension.

In this regard, teachers' willingness to embrace change does not guarantee its success. Ekiz (2004) argues that changing teachers is "a complex and unpredictable event as well as a process that depends upon many other factors such as their past experience, willingness, abilities, social conditions and instructional support" (p. 344). It is only when teachers become aware that their beliefs drive their practices and influence students learning that they re-evaluate and adjust their teaching in ways that are more inclusive and equitable, leading them to review their perception of scientific inquiry (Christodoulou, Varelas & Wenzel, 2009).

For curriculum implementation, not only the pace of implementation should be properly managed so as to handle the relationship between teachers' gradual change and teachers' fundamental change well, but teachers must also be offered necessary support (professional, resources, system and culture) to guide the direction of teachers' change (Yin & Li, 2007, p. 23). Unfortunately, frequently and in many developing countries including Rwanda, teachers perceive themselves as powerless and ineffective cogs in the machinery of change, where changes occur with little if any of their involvement in the preparation and only minor association at the implementation stage. They therefore might feel on occasion that reforms are being made for reform's sake, failing to 'buy into' the need for change, and clearly feeling no ownership of the system or of systemic change.

It has been well argued that attempts to impose change (whatever its nature) on teachers and their practice of teaching have not often been successful (Ekiz, 2004), and therefore "if educational change is to happen, it will require that teachers understand themselves and be understood by others" (Fullan, 1991, p. 117). This might be even more crucial in a country like Rwanda, where most policies including those which are related to education are - in my experience - for the most part top-down. The above reasons may justify why science education reform has also often failed to affect classroom processes or the implemented curriculum (Earnest, 2003).

3.4. SUMMARY OF THEORETICAL FRAMEWORK

Throughout this chapter a theoretical framework for the study was constructed and the related literature reviewed. The study is framed in the constructivist theory of teaching and learning that implies an inquiry-based approach in the science classroom. Within the context of this proposed study, inquiry-based science is looked at with regard to the intended and implemented curriculum in Rwanda. It seems to be too early to consider the achieved curriculum, since this approach has been newly introduced in the lower secondary school science curriculum.

Interpreting the implementation of IBST in Rwandan lower secondary schools was informed by the NRC's (2000) variations of the essential features of an inquiry classroom. Indicative actions of both teachers and learners are best detailed in IAP (2010), describing their interaction during an inquiry-based science lesson. Concerning the type and degree of inquiry, reference was made to the Winning's (2005a) continuum of inquiry that shows the "relative degree of sophistication of various inquiry-oriented intellectual processes" (p. 11). Through the Rwandan curriculum lens, these include a minimum of observing phenomena, performing research, carrying out experiments, collecting and recording data, analysing results, drawing accurate conclusions from experiments and communicating, which are expected to be performed by learners (MINEDUC, 2007b) under the close guidance and unrestricted facilitation of the teacher, who creates and monitors the whole learning environment.

Theories of change were also discussed and helped to understand teachers' change in terms of implementation of an IBST approach. The adaptive change and traditional change theories were among others referred to as part of the framework and informed by Rogan and Grayson's (2003) adaptation of Sergiovanni's typology of forces of change. The interpretation of teachers' responses to change with introduction of inquiry into the implemented science curriculum was made. The above considerations will be taken into account when analysing data and interpreting results in the next two chapters.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

As stated in the introductory chapter, the purpose of this study was to investigate science teachers' responses to the introduction of inquiry into the Rwandan O-level science curriculum. To be more specific, the study investigated the science teachers' understanding of IBST, their attitudes towards the introduction of inquiry into the science curriculum, the activities they were engaged in with regard to IBST and learning, the factors influencing their current practices and their perceptions of what may be done for better implementation of IBST.

The purpose and nature of research questions drive the research design and methodology adopted, as supported by a number of educational researchers such as Cohen, Manion and Morisson (2007); Creswell (2009); Ivankova, Creswell and Plano Clark (2007); and Kane and O'Reilly-de Brun (2001), to cite but a few. This chapter is presented in six focal areas: (a) research design and methodology, (b) participants in the study, (c) the instruments of data collection, (d) data collection procedures, (e) data transformation, and (f) other issues such as validity, reliability and ethical considerations.

4.1. RESEARCH APPROACH

It is also recommended through the scholarly literature to include a section on the methodology, explaining the researcher's ontological or epistemological views. The philosophical research approach underpinning this study is situated in the pragmatic paradigm where the researcher envisaged and used every means available to answer the research questions. Using this approach, according to Kane and O'Reilly-de Brun (2001), a problem or an issue that a researcher is studying determines not only the research design but, more importantly, the research methods and techniques to be used. My adoption of a pragmatic research approach was also motivated by the specific purpose of the study and its contextual factors. This approach has value in providing the theoretical basis for conducting a mixed-method study (McMillan & Schumacher, 2010). Furthermore, the adoption of the

mixed methods design was motivated by the researcher's conviction that pragmatism is the main paradigm associated with mixed-methods research, even though it is not the only one. I further considered some of its many important features, especially by focusing on "what works" in getting research questions answered (Tashakkori & Teddlie, 2003, p. 713), because pragmatism assumes that "substantive issues come before methodological and paradigmatic issues" (Punch, 2009, p. 291). This means that pragmatists tend to be less purist in terms of methods and preconceptions about theory and methods and therefore researchers are more oriented to the production of research results that they would associate with practical ends (Hammerman, 2000).

Underpinned by the pragmatic research approach, mixed methods appeared to best suit the current research problem rather than being bound to either qualitative or quantitative approaches to research. Within this paradigm, the researcher did not commit to either approach but he focused rather on what best works in getting research questions answered (Punch, 2009). For example in order to get views of teachers it was considered important to get in-depth understandings of their views. To do this, interviews would be most appropriate and the data could be analysed from an interpretive perspective in order to make meaning of the multiple views. Where the views of a large number of teachers were needed, a survey could be used and the data interpreted from a post positivist perspective designing and analysing the questionnaire using accepted understandings of inquiry. In this way, the pragmatic research approach allowed the use of multiple epistemological perspectives through the using mixed methods. Figure 4.1 represents the interrelationship between the building blocks of research. In the next two sub-sections issues related to mixed methods and the research design are discussed, specifying decisions made for the present study.

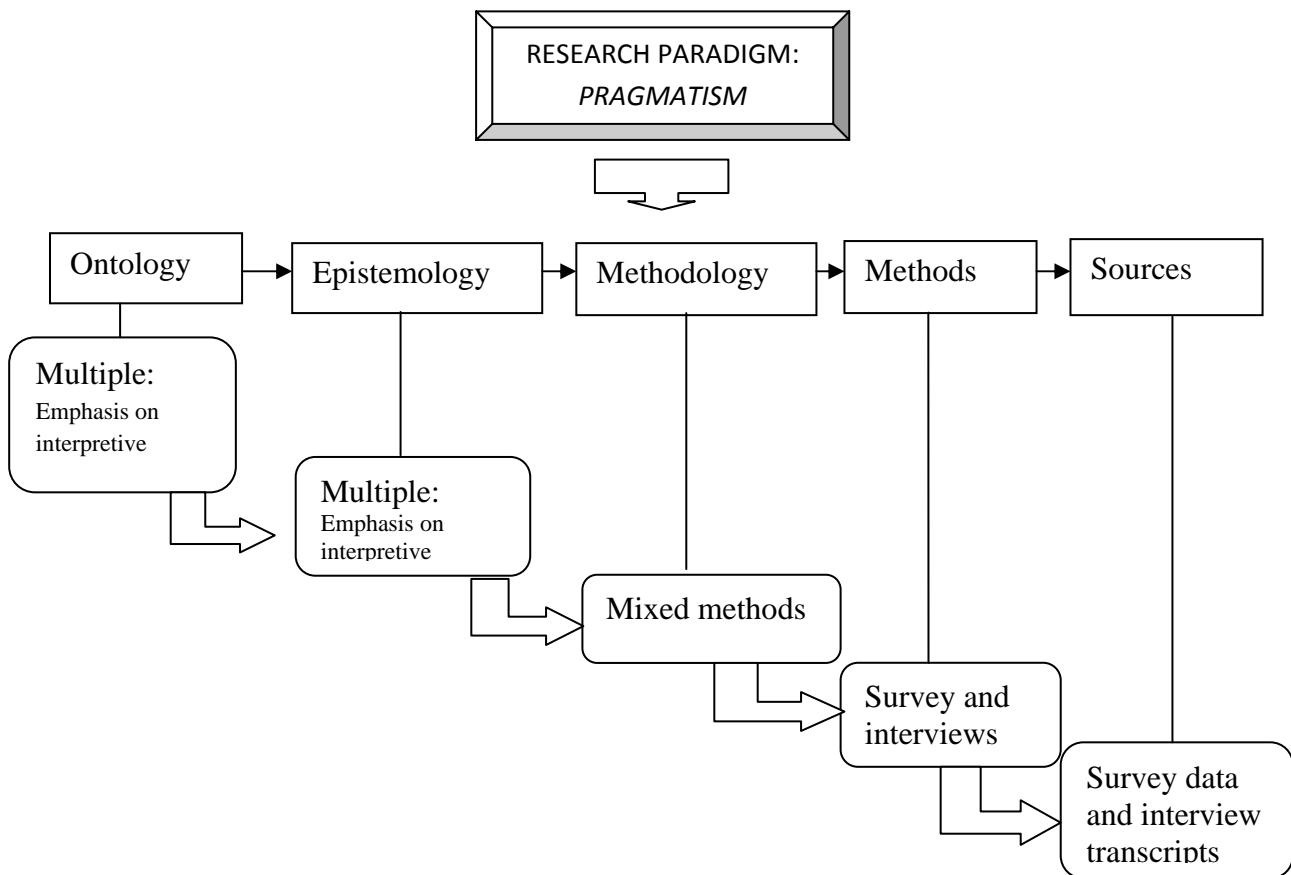


Figure 4. 1. Interrelationship between building blocks of the study
(adapted from Grix, 2002, p. 180).

4.1.1. Mixed-methods

Since the turn of the last century there has been a growth of interest in mixed-methods research, where researchers advocate that the best approach of answering research questions is to use both quantitative and qualitative methods in the same study rather than just one of these (McMillan & Schumacher, 2010). Today mixed- methods research has become popular at the expense of either pure qualitative or quantitative approaches. It plays an important role in educational research, with researchers such as Johnson and Onwuegbuzie (2004) describing it as “a research paradigm whose time has come” (p. 18).

Many researchers have attempted to define mixed-methods research. In their article ‘Toward a definition of mixed methods research’ Johnson, Onwuegbuzie and Turner (2007) examined the criteria which leaders in the field consider important for defining mixed-

methods research. Their analysis of about 19 different definitions from over 20 published mixed-methods researchers revealed strong agreement that mixed research involves both quantitative and qualitative methods. The following serve as illustrations of how a few of these researchers define mixed-methods research, and the way it will be interpreted in this study. According to Johnson and Onwuegbuzie (2004), mixed-methods research is a “class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study” (p. 17). Punch (2009) defined mixed methods research as “a research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry” (p. 298). For the purpose of this study, mixed-methods research was used as a procedure for collecting, analysing and integrating both quantitative and qualitative data at some stage of the research process within a single study for the purpose of gaining a better understanding of the research problem (Creswell, 2009; Tashakkori & Teddlie, 2003).

Other researchers have pointed out the features of the mixed-methods approach. For example, Bazeley (2004) argues that mixed-methods research has regained not just acceptability but popularity, with a significant number of studies emphasizing its virtues in terms of greater understanding and validation of results. Further, Johnson, Onwuegbuzie and Turner (2007) advocate that “mixed methods research is becoming increasingly articulated, attached to research practice, and recognized as the third major research approach or research paradigm, along with qualitative and quantitative” (p. 112) and that it “offers an important approach for generating important research questions and provides warranted answers to those questions” (p.129). This statement was made Johnson and Onwuegbuzie (2004) about three years before in a similar way, also describing mixed-methods research as a third research paradigm after quantitative and qualitative research. Thus, mixed-methods research offers great promise for practicing researchers and today is acknowledged to achieve “increasing acceptance and use across disciplines” (Plano Clark, 2010, p. 428).

The rationale for mixed methods has been advocated by number of contemporary writers, such as Collin, Onwuegbuzie and Sutton (2006); Ivankova, Creswell and Stick (2006); Creswell and Plano Clark (2007); Creswell (2009); Mertens (2010); and Punch (2009), to list but a few. For example, Punch (2009) posits that “the fundamental rationale

behind mixed methods research is that we can learn more about our research topic if we combine the strengths of qualitative research with the strengths of quantitative research while compensating at the same time for the weaknesses of each methods” (p. 290). Johnson and Onwuegbuzie (2004) called this the fundamental principle of mixed methods research consisting of “combining the methods in a way that achieves complementary strengths and non-overlapping weaknesses” (p. 18).

In this study, I adopted a mixed-methods approach, because it appeared to be the best method of shedding light on how research approaches can be mixed fruitfully to offer the best opportunities for answering research questions (Johnson & Onwuegbuzie, 2004). This choice was further driven by the researcher working in a pragmatic research paradigm with an emphasis on the nature of questions to be answered. I was persuaded that using solely quantitative or qualitative methods would be insufficient to provide complete answers that met the purpose of the present study. In order to make the answers useful and more credible, there was a need of exploring general views of a large group of teachers but with the need of a deep understanding of the phenomenon under investigation making a mixed methods approach appropriate.

4.1.2. Mixed methods design

Often understood to be the plan, structure and strategy of investigation conceived so as to obtain answers to the research questions, the research design is described as “plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis” (Creswell, 2009, p. 3). According to Ivankova, Creswell and Plano Clark (2007), like any approach to research, “a mixed methods approach has its set of procedures related to the collection, analysis and mixing the quantitative and qualitative data within a study” (p. 263). Therefore the selection and implementation of these procedures related to the specific mixed-methods research design depends on the purpose of the study. In this case, the choice of design in a mixed-methods study was governed by the inherent logic of the research project, and especially by the way its research questions were asked and phrased (Punch, 2009). However, before describing the particular design considered for the present study, it was thought important to briefly review the main types of mixed-methods research designs. By so doing, my intention is not to espouse preferentially the ideas of any

of the authors who discussed and attempted to classify mixed-methods research designs (Creswell, 2009; Ivankova, Creswell & Stick, 2006; Ivankova, Creswell & Plano Clark, 2007; McMillan & Schumacker, 2010; Punch, 2009), rather it is about considering what they have commonly agreed upon as types of mixed-methods research designs. In fact, mixed-methods designs can differ to a great extent, depending on the purpose of the research, the sequence used and the emphasis given to each method. Punch (2009, pp. 297-298) lists four types of mixed methods designs namely (a) a triangulation design, (b) an embedded design, (c) an explanatory design, and (d) an explanatory design. Creswell (2009) provided a more detailed typology of these mixed-methods research designs by considering the time, the order in which methods are used, the weighting-relative importance for each, and how methods and data are mixed when combining the approaches. In this study, carried out within a pragmatic research approach, I opted to use an explanatory sequential mixed-methods design, involving collecting quantitative data first and then explaining the quantitative results with in-depth qualitative data (Creswell & Plano Clark, 2011), since I was persuaded that collecting diverse types of data would provide a deeper understanding of my research problem and therefore answer the research questions. The sequence adopted in this study is summarized in Figure 4.2.

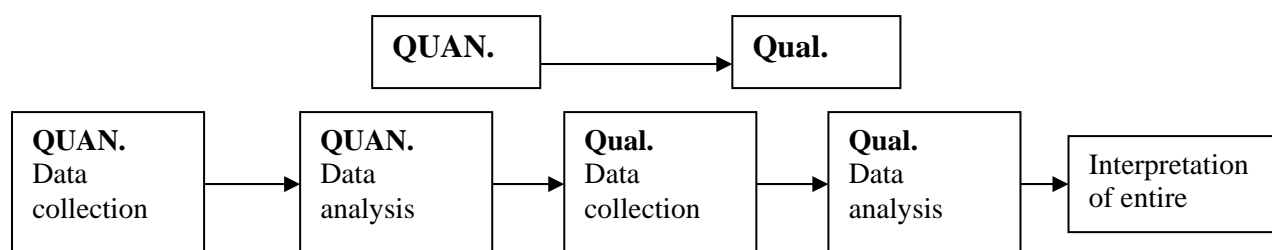


Figure 4. 2. Explanatory sequential design used (adapted from Creswell, 2009, p. 209)

The first phase of the sequence consisted of a broad survey in order to generalize results to a population, and the second phase consisted of an illuminative case study where data was collected by means of open-ended interviews enabling more insight to be gained into the views of a few selected science teachers. The two approaches were then combined in order to provide an in-depth picture, as argued by Creswell (2009) that “there is more insight to be gained from the combination of both qualitative and quantitative research than either form by itself” (p. 203) and Ivankova, et al. (2007), pointing out that “a study that employs mixed methods approach would be the use of a survey to first establish attitudes of

participants towards a topic and then follow-up with in-depth interviews to learn about individual perceptions on the topic” (p. 206). The researcher’s decision to adopt this design was partially inspired and informed by Creswell and Plano Clark (2011)’s recommendations for designing a mixed-methods study. They include decisions relating to individuals participating in two phases, the relative size of the two samples, multiple options of designing the qualitative data collection based on the quantitative results, how to select the best individuals for the second phase and the related follow-up as well as the nature of the follow-up itself.

4.2. PARTICIPANTS IN THE STUDY

When engaged in research, especially social and educational work, there are always people, events or phenomena to be studied and from which information would be sought or collected by relevant and appropriate means. In social science the key concepts are the population, referred to as the total target group, who would in the real world, be the subject of the research and about whom one may say something, and the sample, referred to as the actual group which is included in the study and from whom the data are collected. These two concepts are discussed below and a detailed description of those involved in the present study is provided.

4.2.1. The population

Various authors have attempted to define the concept of population in the field of research (Bless & Higson-Smith (2000); Gravettez & Forzano (2003); McBuney (2001); Monette, Sullivan & Dejong (2008); Powers, Meenaghan & Toomey (1985); Punch (2009); Strydom (2005a), and all have reached agreement that it is the entity from which the sample is extracted for the purpose of a study. They couldn’t isolate the concept of population from that of sample, for the latter is always “drawn from a population, which refers to all possible cases of what one is interested in studying” (Monette, Sullivan & Dejong, 2008, p. 130). Some would argue that a population is a set of entities in which all measurements of interest to the researcher are represented (Powers, Meenaghan & Toomey, 1985), while others see it

as “the set of elements that the research focuses upon and to which obtained results should be generalized” (Bless & Higson-Smith, 2000, p. 85). Strydom (2005) summarizes all these views, saying that “a population is the totality of persons, events, organization units, cases records or other sampling units with which the research problem is concerned” (p. 194).

In this study the concerned population is made up by all science teachers at lower secondary school in Rwanda. This level represents a large proportion of the secondary schools in Rwanda, for it has recently increased considerably in terms of enrolment and creation of new schools in response to the policy of the nine years of basic education programme mentioned in the introductory chapter. In schools hosting both lower and upper secondary levels, it sometimes happens that some teachers teach at both levels. In such cases, those teachers would also be part of the concerned population in the present study. These teachers are those that were in place during the 2009 and 2010 academic years.

4.2.2. The sample

According to Strydom (2005), it is imperative to clearly understanding the concept of sampling before engaging in conducting research, for it is the most important concept in the total research endeavour. Fraenkel and Wallen (2007) emphasize this role of sampling, arguing that “one of the most important steps in the research process in the selection of the sample of individuals who will participate either by being observed or questioned” (p. 92). Therefore, all research, whether quantitative, qualitative or both, involves sampling because no study can include everything, as emphasized by Miles and Huberman (1994) that “you cannot study everyone everywhere doing everything” (p. 27). The main reason for sampling is based on feasibility: more often the whole group might be so large that, beside the time, cost and other resources that may be involved, studying it is not feasible. Another reason for sampling is that, surprising as it may seem, “we can get better information from carefully drawn samples than we can from an entire group” (Monette et al., 2008, p. 130). Based on the above considerations, it was found necessary to take into account a variety of sampling techniques.

Many authors, such as Creswell (2009), Fraenkel and Wallen (2007), Maree and Pietersen (2007), Monette et al. (2008), to cite but a few, have attempted to describe and classify sampling methods, and all agree upon two categories of sampling methods, namely

probability and non-probability sampling. In probability sampling, subjects are drawn from a larger population and ideally individually are randomly chosen, giving each person in the population a known chance of being selected. Simple random, systematic and stratified sampling procedures fall under probability sampling. In non-probability sampling, the researcher uses subjects who happen to be accessible or who may represent a certain type of characteristics. Non-probability sampling comprises convenience or availability sampling, quota sampling, snowball sampling, and purposive sampling (also called judgmental sampling).

As the present study is designed as mixed-methods research, the selection of participants included non-probability quantitative approaches to sampling and purposive qualitative approaches. In fact, when using mixed methods sampling procedures should be considered and in the most desirable case samples of both methods should be nested within each other (Yin, 2006). This applies to the present study, where the fieldwork sample for the qualitative approach is nested within the survey sample for the quantitative approach.

The logic underpinning quantitative sampling is that the researcher analyses data collected from the sample, but wishes to make statements about the whole population from which the sample was drawn. Thus, a sample would be understood as a smaller group that is actually studied drawn from a larger population, data being collected and analyzed from it, and then inferences made to the population within a relationship that can be represented as shown in Figure 4.3.

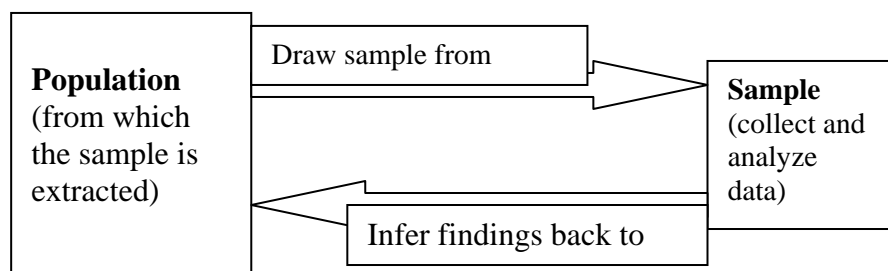


Figure 4. 3. Population and sample (adapted from Punch, 2009, p. 251)

In a quantitative research approach the sample size is generally large and is ideally randomly selected from the larger population to enable generalization of the results to this population. However, in some cases the researcher uses convenience sampling, which consists of selecting the individuals who are available and willing to participate in the study (Ivankova, et al., 2007). The idea behind qualitative research is to purposefully select participants that would best help the researcher understand the problem and the research questions. There are a variety of procedures in qualitative research recalling the prominent terms such as transforming, interpreting and making sense of qualitative data. From samples in qualitative studies, concepts are developed inductively from the data and raised to a higher level of abstraction (Punch, 2009). The method of sampling in analytic induction is purposeful sampling, where the subjects included in the study are chosen because they are believed to facilitate expansion of the developing theory. This is in opposition to random sampling, which ensures that characteristics of the subjects appear in the same proportion that they appear in the total population.

In qualitative research the sample size is generally small and is purposefully selected from individuals who have the most experience with the studied phenomenon, from whom the researcher collects data in the form of words or text and images or pictures about the central phenomenon (Platton, 2002). By means of samples Ivankova et al. (2007) identified the main types of qualitative data that can be collected in relation to the goal of qualitative research, namely to explore and understand a central phenomenon. These include: (a) individual and focus group interviews, resulting in transcripts of interviews with the participants; (b) observations, through which notes and pictures are taken by the researcher during the observation; (c) documents, including public and/or private records about the studied phenomenon; (d) audiovisual materials, including pictures or audio recordings of people, places or events; and (e) artefacts, such as materials used by a particular group of people. In the present study the two first types of data were collected by means of individual interviews and notes taken during classroom observations, and were guided by the results from the first phase of the sequence that was adopted.

For the first phase of this study I felt at first glance that the sampling method would be stratified, with proportional allocation of sample size considering five strata made up of the four provinces of Rwanda and Kigali (the capital city). However, I found it more

appropriate to adopt the purposive sampling method. I used my own judgement to consider a number of other characteristics of the population (Mertler & Charles, 2008), that may better draw a more representative sample beyond the mere matter of numbers. In such sampling methods, “investigators use their judgment and prior knowledge to choose for sample people who best serve the purpose of the study” (Monette et al., 2008, p. 148). Thus, apart from being science teachers at lower secondary level regardless of their major science specialization, the participants were selected from all types of schools countrywide on the basis of a range of criteria, including whether the school was public, private or government subsidized and single-sex or co-educational, whether it was located in a rural, peri-urban or urban area, resourced or under-resourced, to list but a few. This was done with the aim of getting countrywide representativeness. Based on the above consideration the survey was conducted on a sample of about 200 science teachers.

In the second phase sequence, a purposeful sample of 15 teachers was considered for interviews supplemented by some contextual observations. The selection was based on similar criteria used in selecting teachers surveyed during the first phase. This second phase aimed at seeking more in-depth explanation of findings from the survey, and therefore the interview schedule was developed in the light of the data and findings from the first phase in respect to the design of the study, which was explanatory sequential mixed-methods research. As for the observation, its role was limited at gaining contextual rather than analytical information.

4.3. INSTRUMENTS OF DATA COLLECTION

The nature and design of the study determine the type of data to be collected and therefore the instruments to be used. As the present study was designed in a mixed-methods approach, both quantitative and qualitative data were collected and each type of data required a specific data collection instrument. The instruments of data collection used in this study are discussed below.

4.3.1. Phase 1: Survey questionnaire

In the field of research the term ‘survey’ designates a specific way of collecting data and identifies a broad research strategy. The survey data collection involves gathering information from individuals, called respondents, by having them respond to questions (Monette et al., 2008). It consists of asking questions of a sample of people in a relatively short time, and then testing hypotheses or describing a situation based on their answers. This last aspect is that which prevailed in the present study, for no hypotheses were to be tested; rather it was about finding out the teachers’ responses to an innovation brought into their daily practices of science teaching through inquiry. Although a survey can have different forms, data collected are basically what people say to the researcher in response to questions.

One of the basic ways of collecting data in a survey is the questionnaire, also the most generally used instrument. Dörnyei (2003) associates its popularity to the fact that it is easy to construct, extremely versatile, and uniquely capable of gathering a large amount of information quickly in a form that is readily processable. He further argues that “a typical questionnaire is a highly structured data collection instrument, with most items either asking about very specific pieces of information or giving various responses options for the respondent to choose from, making the questionnaire data particularly suited for quantitative, statistical analysis” (p. 14).

Although the term questionnaire is one that most researchers are familiar with, it is not straightforward to provide a precise definition of it. The *New Dictionary of Social Work* (1985) defines a questionnaire as “a set of questions on a form which is completed by the respondent in respect of a research project” (p. 51). Brown (2001) expands the definition by including the alternative ways of answering questionnaires: “questionnaires are any written instruments that present respondents with a series of questions or statements to which they are to react either by writing out their answers or selecting from among existing answers” (p. 6). The basic objective of a questionnaire is to obtain facts and opinions about a phenomenon from people who are informed on the particular issues (Delpont & Roestenburg, 2005). There are two basic categories of questions used in a questionnaire, namely closed-ended and open-ended questions. The first category of questions provides respondents with a fixed set of alternatives from which to choose, while the second requires respondents to write responses, as for an essay-type examination question (Monette et al., 2008). For the purpose of this

study the two types of questions were mixed in the same questionnaire, even though it seems that the closed-ended type outweighed the open-ended.

Depending on what the researcher intends to measure, know or describe, the questionnaire contains a further three types of questions that fall into three broad categories (Dörnyei, 2003, p. 8):

1. Factual questions, also called classification questions. These are used to find out who the respondents are, often covering the respondent's demographic characteristics or any other background information that may be relevant to interpreting the finding of the survey. In this study such questions were grouped under a section entitled 'bibliographical data' (see Section 1 of the questionnaire in Appendix A).
2. Behavioural questions, which typically ask about people's actions, habits, lifestyles and personal history. This category did not dominate in the questionnaire used in this study, considering its purpose and therefore the research questions.
3. Attitudinal questions concern respondents' attitudes, opinions, beliefs, interests and values, and this group of questions was represented in almost all of the five sections of the questionnaire used in the present study.

The questionnaire as a data collection instrument presents both advantages and disadvantages. As reported by Dörnyei (2003), the main attraction of the questionnaire is its unprecedented efficiency in terms of (a) researcher time, (b) researcher effort, and (c) financial resources. A written questionnaire tends to be more reliable because it is anonymous, encourages greater honesty, is economical in terms of time and money, and there is a possibility that it can be mailed, reducing charges related to travelling to reach respondents (Cohen et al., 2007). Furthermore, if the questionnaire is well constructed, processing the data can be fast and straightforward, especially by using some modern computer software. Besides the advantage of cost-effectiveness, its versatility constitutes an additional feature.

On the other hand, its disadvantages are that there is often a low rate of returns and for any questionnaire there is a need to pilot it and refine many of its aspects, including the content, wording and length appropriate for the targeted sample. Also, since the researcher does not

normally interact with the respondents, a written questionnaire needs more care and attention from its construction to the processing via its administration. Despite their popularity, questionnaires have been accused of weaknesses such, the simplicity and superficiality of answers; unreliable and unmotivated respondents; respondent literacy problems; little or no opportunity to correct respondents' mistakes; social desirability or prestige bias; self-deception; acquiescence bias; halo effect; and fatigue effect (Cohen et al., 2007).

Although the relevant literature contains a significant body of accumulated experiences and research evidence about how to minimize the effects of potential problems associated with self-completed questionnaires, there is no single recipe for success yet available. Only the researcher's skills added to experience may guarantee that the instrument enables collecting of accurate data, and therefore measures what is really supposed to be measured. As far as I was concerned, in this study every effort and required precaution was taken to ensure that the questionnaire used was as accurate as possible.

4.3.2. Phase 2: Interview and observation

For the second phase of this study two methods of data collection, namely interviews and observations, were used. These two methods of qualitative data collection are not exclusive of each other, since it is acknowledged that interviews may be employed in conjunction with other techniques such as participant observation or document analysis (Bogdan & Biklen, 1992). Confidence in the use of these two data collection instruments was informed by Cohen et al.'s view (2000) that interviews enable both interviewers and interviewees to discuss their interpretation of the world in which they live, and to express how they regard situations from their point of view, while observation methods provide the researcher with ways to check for non-verbal expression of feelings. These two methods are discussed in detail in the following sections.

The interview is the most prominent and predominant mode of data collection in qualitative research, and described as a good way of accessing people's perceptions, meanings, definitions of situations as well as constructions of reality, and therefore a most powerful way of understanding others (Fraenkel & Wallen, 2007; Greff, 2005; Punch, 2009). As pointed out by Punch (2009), arguing that even though interviewing is basically about

asking questions and receiving answers, it is acknowledged that there is much more to it than that due to the many aspects it involves. These aspects filter through the range of attempts to define the concept of 'interview'.

For example, Nieuwenhuis (2007) defines an interview as a two-way conversation in which the interviewer asks the participant questions to collect data and learn about the ideas, beliefs, views, opinions and behaviours of the participant. It aims at obtaining rich descriptive data that would help the researcher to understand the participant's construction of social inquiry that drives the research. Interviews are used to gather descriptive data, as was the case in this study, in the participants' own words so that the researcher can develop insights into how participants interpret some aspects of the world (Bogdan & Biklen, 1992).

There is a lot of literature about different types of interviews (Cohen et al., 2007; Fraenkel & Wallen, 2007; Monette et al., 2008; Punch, 2009). However, whichever typology, the important dimension of such a variety is all about the extent to which the interview is structured and how deep it tries to go. Structurally, interviews can be displayed in a continuum, from the structured to the unstructured, also called open-ended interviews, with the semi-structured interview in between. In structured interviews the schedule or guide is pre-established and questions developed in advance, with pre-set response categories. Responses in this type of interviews are fixed and the respondent chooses from among the fixed responses. Flexibility and variation are minimized, while standardization is maximized. In this regard Fraenkel and Wallen (2007) pointed out three strengths of using a structured interview: (a) data analysis is simple, (b) responses can be directly compared and easily aggregated, and (c) many questions can be asked in a short time. Its weaknesses are that: (a) respondents must fit their experiences and feelings into the researcher's categories, (b) it can distort what respondents really mean or have experienced by limiting their response choices, and (c) it may be perceived as impersonal, irrelevant, and mechanistic. At the other end of the continuum there is the unstructured interview, described as a non-standardized, in-depth and open-ended interview. This type of interview normally takes longer, in the form of a conversation, where participants may provide more insight into the event or phenomenon being studied. Punch (2009) sees it as a powerful education research tool capable of producing rich and valuable data, for it enables an exploration of people's interpretations and meanings of events and situations compared to the structured version.

There are a number of ways of conducting interviews. The researcher can conduct a face-to-face interview with participants, can interview them by telephone or engage in focus group interviews. Whichever way is adopted, the most important aspect to keep in mind is that the interview is a social, interpersonal encounter, and not merely a data collection exercise (Cohen et al., 2007), and therefore requires a number of precautions, mostly on the side of the researcher. For the purpose of this study and as guided by research design, semi-structured and face-to-face interviews were used. This choice was made in order to gain a more detailed picture of participants on a number of issues that emerged from the survey phase of the study. Although a set of predetermined questions on the schedule guided the interview, both researcher and participants had more flexibility, enabling the researcher to follow-up particular issues that emerged in the course of the interview, and the participant to give a fuller picture in as much detail as possible (Greff, 2005).

Although interviews can provide a researcher with information about people's attitudes, values and what they think and say they do, there is no substitute for watching them if one wants to know what they actually do. That is why this third tool of data collection was also considered but without aiming at collecting analytical data, rather at providing contextual information about how and under which conditions teaching and learning of science was taking place in schools visited. I adopted a passive observation as a way of not interfering with the normal course of school activities. However, even though the observation was scheduled in the sense that I knew in advance which aspects were to be observed, there was no restriction as any other interesting emerging information could not be passed by.

4.4. DATA COLLECTION PROCEDURES

This study was designed as a mixed-methods research approach and both quantitative and qualitative data were collected in two sequential phases. The first phase consisted of a survey by means of a semi-structured questionnaire, while in the second phase data were collected by means of interviews and limited observations, as described in section 4.3 above. The following sections discuss the data production procedures for each of these two phases. It is obvious that the second phase was informed by the results from the first phase.

4.4.1. Phase one of data collection

In the first phase data were collected from science teachers by means of a survey questionnaire (Appendix A) which was administered to a purposeful sample of 200 teachers, as described in section 4.2.2. However, before engaging in this phase the questionnaire was first piloted. As pointed out by Dörnyei (2003), regardless of how experienced the questionnaire designer is, any attempt to shortcut the piloting stage may seriously jeopardize the quality of the questionnaire. It is even said that “if you do not have resources to pilot-test your questionnaire don’t do the study” (Dörnyei, 2003, p. 64). Emphasizing the role of piloting the questionnaire, Cohen, Manion and Morrisson (2000) argue that a pilot is highly recommendable for the questionnaire’s success, because it serves not only to increase the reliability and validity but also its practicability. Furthermore, the pilot study enables the researcher to: (a) ensure the clarity of the questionnaire, (b) estimate the time taken to complete the questionnaire, (c) identify repetitive questions, (d) identify misunderstandings, and (e) try out the coding for data analysis.

In this study the questionnaire version that was piloted resulted from a long revision and discussion between the researcher and the supervisor, which aimed at producing a questionnaire that not only fitted with the research questions but also could be completed easily by respondents. There is no shortcut for this practice, as pointed out by Oppenheim (1992): “questionnaires do not emerge fully-fledged, they have to be created or adapted, fashioned and developed to maturity after many abortive test flights and every aspect of a survey has to be tried out beforehand to make sure that it would work as intended” (p. 47). The researcher took this step seriously despite the practical difficulties that were involved, especially the distance and associated resources to reach the research site and prospective respondents.

Thus, pilot questionnaires were sent to the site and distributed to 15 science teachers, of whom 12 completed and returned them. For the sake of optimizing the outcome of piloting the questionnaire, the researcher provided space for criticisms and/or comments that were then carefully considered for the main investigation (Strydom, 2005b). Analysis of the pilot study revealed that the questionnaire was long, and in the light of the respondents’ comments

a few changes were made, including reformulation and omission of questions that were found not to be clear.

After this step the final version of the questionnaire was administered to 200 science teachers during the third term of the 2009/2010 academic year. The researcher was meeting participant teachers in their respective schools, which is why it took a relatively long period of time. For some science teachers the completed questionnaires were collected on the same day they were administered, while others needed more time, requiring the researcher to leave and come back later for collection. At the end of the exercise of collecting completed questionnaires and checking the completeness, nine were rejected and only 150 completed questionnaires were retained.

Like any research endeavour, this phase of data collection was not without inherent problems. Although the researcher was aware and prepared to deal with any contingency, he experienced problems in getting back the questionnaires from some teachers in very remote areas when it was not done on the same day of administration. However, the fact that there is now a telephone network countrywide and almost all teachers have cell phones helped a lot, especially for follow-up and making appointments with teachers in order to collect the completed questionnaires.

4.4.2. Phase two of data collection

As stated in the previous sections, this phase of the sequential design was about collecting data by means of semi-structured one-on-one interviews with 15 purposefully selected science teachers and classroom observations. All interviews took place at schools in a place and at a time agreed upon between the teachers and the researcher after introductions were made and cooperation granted. Although with semi-structured interviews the researcher would have a set of predetermined questions on an interview schedule, in this case the interviews were guided by the schedule rather than dictated by it. Participants were provided with a full opportunity to state in an open-ended way whatever they wanted to in relation to the topic being investigated.

On the basis of the permission sought and obtained from each participant, the interview was tape-recorded and later transcribed for purposes of analysis. To deal with the discomfort associated with the recording, after the interview I played back the tape to some interviewees who requested it. This provided added value to the data and was highly appreciated, since two of those who requested to listen to the recording brought in some clarification to what they said during the interview. This additional information was noted and added to the transcript they were referring to.

It is acknowledged that for the interview to be successful, a number of precautions have to be taken into account. The researcher's experience and familiarity with the field were not by themselves a guarantee of success; they were paired with other important practices, as suggested by Fraenkel and Wallen (2007, pp. 458-9), that include:

1. To respect the individual being interviewed;
2. To be as natural as possible to avoid deception in any form;
3. To develop an appropriate rapport with the participant;
4. To ask the same question in a different way when it appears necessary;
5. To ask the interviewee to repeat an answer or a statement when there is some doubt about the completeness of a remark; and
6. To avoid leading questions.

This step of data collection was successful since no incidents were recorded before, during or after interviews. Most importantly, I tried my best to not interfere with their teaching time tables, and in some cases had to wait for many hours until they were fully available.

To supplement the data collected from interviews, a number of observations were done. However, the observations were not analysed in detail. It was found that the observations were not always directly applicable to inquiry based lessons. In some cases teachers were not prepared for observation despite earlier requests and in other cases very little could be observed in the lesson related to inquiry. For this reason the observations were not systematically analysed. They rather served the purpose of providing information about the resource context within which teaching of inquiry (when it was planned) was taking place. As a reminder, the observation was rather contextual than analytical. Besides the ten lessons that were observed, the observations included in the schools, a look at science school facilities such as laboratories and science kits where available, textbooks, and so forth. The

aim was more to obtain contextual data than to collect analytical data. Like for interviews, permission from teachers was sought to observe their lessons and had to be granted first. As a non-participant observer I tried to work in an unobtrusive manner as possible.

4.5. DATA TRANSFORMATION

After the data collection exercise the next step in this mixed-methods research process was the data analysis. As suggested by Onwuegbuzie and Teddlie (2003), “the point at which the data analysis begins and ends depends on the type of data collected, which in turn depends on the sample size, which in turns depends on the research design, which in turn depends on the research purpose” (p. 351). In this study, designed as a sequential mixed model, it was expected that the sequence that prevailed in data collection would be so in the data analysis as well as in inference. At this stage the researcher’s ingenuity is called upon since it is a phase that brings the “data to speak”.

Once the raw data have been collected the researcher’s task consisted of what is called reduction of the mass of data gathered into a form that is suitable for analysis. In fact, such raw data are still yet in a highly inconvenient form from the standpoint of deriving usable meaning from them. Considering the design of the present study, preparation for data analysis was done in respect of two types of data involved in the study, and the process of data reduction included coding data and editing, consisting of identifying and eliminating errors made by respondents in preparation for analysis. The next task was that of coding. Coding refers to the process by which the researcher transforms raw data into a machine-readable format suitable for data analysis. Two aspects are normally taken into account when coding: the researcher considers the data source (the completed questionnaire in this case) and determines how to translate data into a coded form which is cognizant of the capabilities and restrictions of the computer program used to analyse data (Monette et al., 2008). In this case the computer program used was the Statistical Package for Social Scientists (SPSS) version 19. The assignment of a code to each answer resulted in developing and producing the first codebook. This should be done in such a way that all information is coded. The codebook for the data set is an inventory of all the individual items in the data collection instrument, and

provides lasting documentation on how the data set is constructed and is therefore invaluable for data file management. The codebook is normally prepared before data are entered into the computer, and is therefore used as a guide for the next phase – the data entry. This phase, that precedes the effective data analysis, is fundamental. It aims at producing a complete data set that the data analysis software program can access and process. This exercise does not require high expertise, since some modern statistical packages for the PC such as SPSS include full featured data-entry facilities.

Once the data entry was done, the analysis was ready to be undertaken. However, it is recommended that another step be undertaken, that of data cleaning. No matter how much care the researcher takes during the data-entry process, errors can be expected, such as skipping variables for certain cases, entering the wrong value, or entering the value in the wrong location (Monette et al., 2008). Before the analysis began the researcher cleaned the data by examining them carefully and making any corrections needed, because some errors can cause the analysis program to abort a statistical procedure or seriously distort the findings of the analysis.

The next set of data, collected in the second phase, was qualitative in nature. According to Nieuwenhuis (2007) qualitative data come in many forms and from a variety of sources, all producing raw text or narrative data varying from brief responses to open-ended story-telling. Before the researcher attempts analysis, there are a number of stages that the raw data have to undergo. The raw data must be organized, transcribed, and saved, and the researcher has to know the data well. These steps ease the coding process that is crucial before data analysis takes place.

The interviews were audio tape-recorded, known as a standard method of capturing interview data. I did not seek any assistance in this; as suggested by Hesse-Biber and Leavy (2006), the process of transcription should be undertaken by the researcher as part of the data analysis process engendered by interacting with the data in an intensive and intimate way. Convinced of the crucial importance of transcribing one's interviews oneself, I personally fully transcribed each interview and read through the transcripts several times to pinpoint salient themes or patterns. It is important that the researcher gets to know the data inside out. I had to read and reread the transcripts, and whenever needed to play back the tape and listen to it several times again, because the better the researcher knows the data, the more

competent he/she will be in labelling units of meaning (Henning, Van Rensburg & Smit, 2004).

Although the transcribing process is certainly laborious, it is the most valuable part of the research because it brings the researcher close to the data (Denscombe, 2003), and it is therefore recommended that it be done by the researcher him/herself in order to include non-verbal cues. This is also a crucial step for there is the potential for massive data loss, distortion and reduction of complexity (Cohen et al., 2007). Denscombe emphasizes the complexity of transcribing, arguing that “transcription is not a mechanical process of putting tape-recorded talk into written sentences but that the talk needs to be tidied up and edited a little to put in a format on the written page that is understandable to the reader” (p. 184).

The next step before the data analysis itself was the data coding. In qualitative data “coding is a process of reading carefully through the transcribed data, line by line, and dividing it into meaningful analytical units” (Nieuwenhuis, 2007, p. 105). It consists of marking the segments of data with symbols, descriptive words or unique identifying names. The coding process therefore enables researchers to quickly retrieve and collect together all the text and other data that they have associated with some thematic ideas, so that the sorted bits can be examined together and different cases compared. Due to the inherent flexibility in qualitative data procedures, the coding is flexible and allows one to move back and forth between steps as new insights emerge from the data sources, and even to review the coding.

Once the transcribed data were coded, the next step was to organize and combine related codes into themes or categories. It is recommended that before moving to the next steps, namely structuring and interpreting data, the researcher rereads initial transcripts to check whether all the essential insights that emerged from the data were captured (Nieuwenhuis, 2007). The interpretation of analyzed data would then search for emerging patterns, associations, concepts and explanations of the data. It is at this stage that the researcher may engage in defining concepts, mapping the range and nature of phenomena, creating typologies, finding associations with data, providing explanations or developing strategies.

In this case, where the two approaches were combined in a single study, it is at this stage that the findings from the qualitative data are associated with those from the

quantitative data as a way of generating more meaning and thereby enhancing the quality of data interpretation. This enables the researcher to fulfil the five purposes of mixed-methods evaluations: (a) triangulation as a way of seeking convergence and corroboration of results from different methods studying the same phenomenon, (b) complementarity in seeking elaboration, enhancement, illustration and clarification of the results from one method with results from the other method, (c) development in using the results from one method to help inform the other, (d) initiation consisting of discovering paradoxes and contradictions, and (e) expansion, seeking to expand the breadth and range of research by using different methods for different research components (Onwuegbuzie & Teddlie, 2003).

The second phase of data collection also involved observations. However as reported earlier, data from this source served as illuminating some aspects that were reported through interviews but were not for analysis purpose. In the classroom the following aspects were observed while taking note of any other interesting information: the classroom setting, availability and use of teaching aids, type of activities and how they were carried out, and teacher-learner interactions. A personal reflection was made as to whether the inquiry approach had been used and to what extent. In reporting, it was initially thought to have one chapter (Chapter Five) on the data analysis and findings. However, as the analysis was going on it was realized that this chapter would be disproportionately large, so I opted to split it into two separate chapters. I considered the most closely related research questions and put them into themes, retained as chapters' headings, making a total of seven chapters. The following and last section of this chapter discusses two particular issues, namely ethical issues and the validity and reliability of the study.

4.6. OTHER ISSUES

4.6.1. Ethical considerations

Empirical research in education inevitably carries ethical issues, because it involves data from and about people, who have both rights and feelings, and therefore special considerations apply (Monette et al., 2008). Although the concept 'ethics' is emotionally charged and surrounded with hidden meaning, it can be simply referred to in research as

principles of right and wrong that a particular group accepts (Bogdan & Biklen, 1992). Even though ethical issues arise in quantitative, qualitative and mixed-methods approaches, they are sometimes more acute in qualitative approaches, because while all social research constitutes to some extent intrusion into people's lives, qualitative research often intrudes more (Punch, 2009). These issues can arise early in the research project, as the research progresses or after the study, and therefore "each stage in the research sequence may be a potential source of ethical problems" (Cohen et al., 2000, p. 49). Depending on when they arise in the course of research, Punch (2009, pp. 50-51) listed ethical issues in three categories, as follows:

1. Ethical issues arising early in the research project, including the worthiness of the project, competence boundaries, informed consent and benefits, costs and reciprocity;
2. Ethical issues arising as the research progresses, including harm and risk, honesty and trust, privacy and intervention and advocacy; and
3. Ethical issues arising later in or after the project, including research integrity and quality, ownership of data and conclusions, and use and misuse of results.

This list is not exhaustive. However, in the field of research with human subjects, only three issues dominate recent guidelines of ethics, namely informed consent, the protection of subjects from harm, and the right to privacy (Bogdan & Biklen, 1994; Cohen et al., 2007; Fraenkel & Wallen, 2007; Monette et al., 2008; Punch, 2009). The first ensures that subjects enter research projects voluntarily after a clear understanding of the nature of the study and the dangers and obligations that are involved, while the second attempts to ensure that subjects are not exposed to risks that are greater than the gains, if any, that they might derive (Bogdan & Biklen, 1994). As for the right of privacy, it is clear that any attempt to collect data from people raises the issue of privacy and confronts researchers with the dilemma of whether threats to privacy are warranted by the research.

Informed consent is considered a central canon of research policy, and was sought before any attempt at field work. It refers to telling potential research participants about all aspects of the research that might reasonably influence the decision to participate (Monette et al., 2008). Regarding the protection of subjects from harm, even though research in the human sciences rarely involves physical dangers, researchers should always avoid exposing participants to physical or mental distress or dangers, and whenever any potential for such

distress exists the participants should be fully informed, and it is then the researcher's obligation to alleviate the impact of whatever distress may occur.

As stated before, intrusions into human's privacy have considerably increased in modern society with the growth of social research. Unfortunately the right to privacy is often a difficult issue to resolve. Researchers have come up with three major ways of dealing with the problem of protecting participants' privacy, including: (a) letting subjects edit their responses; (b) keeping the data anonymous, and (c) keeping the data confidential (Monette et al., 2008, p. 56). This first way consists of offering participants the opportunity, after the data have been collected, of destroying any data that they wish to remain private. In this study this occurred when some participants requested listening to the audio tape-recording of their interviews, a request to which the researcher conceded. The second way of ensuring the participants' anonymity means that no one apart than the researcher him/herself can link any data to a particular respondent. Researchers often turn to a third way of protecting privacy through confidentiality, which means ensuring that data collected from participants in the study are not made public in a way that can be linked to an individual.

In this study all of these issues were carefully taken into account, and none of the related activities was undertaken before permission in the form of informed consent had been given by participants. Importantly, with regard to ethical considerations, I had to comply with the ethical clearance policy of the University of KwaZulu-Natal. I therefore went through the process of application for ethical clearance, and the ethical clearance certificate was granted after consideration by the Faculty Higher Degree Committee, allowing me to undertake the field work (see Appendix C).

4.6.2. Validity and reliability

Creswell and Plano Clark (2011) define validity in mixed-methods research as a way of "employing strategies that address potential issues in data collection, data analysis, and the interpretations that might compromise the merging or connecting of the quantitative and qualitative strands of the study and the conclusions drawn from the combination" (p. 239). In this study I was concerned about dealing with issues of validity and reliability, being aware that it is very easy to slip into invalidity, since it can enter at any stage of research (Cohen et al., 2000). Furthermore, Golafshani (2003) argues that validity and reliability are two factors

which any researcher should be concerned about while designing a study, analyzing results and judging the quality of the study.

An issue, given the bilingual nature of schooling in Rwanda, was the language used in the questionnaires and interviews. Participants were given the opportunity to use either English or French depending on the language they felt they were more fluent. Therefore, the researcher had to deal with the issue of translation. Originally, all data collection instruments were designed in English and were then translated into French. For both instruments and data collected, the translation was done primarily by the researcher himself, who is a fluent French and English speaker. These translations were then checked by a colleague who is also a researcher in the same field of science education and also fluent in both languages.

Due to the divergence of researchers' viewpoints, where the term 'validity' is routinely used in quantitative research and disliked by many qualitative researchers, a possible term that is acceptable by both quantitative and qualitative researchers and that the researcher consented to use is 'legitimation' (Onwuegbuzie & Johnson, 2006, p. 55). The legitimation of the mixed-methods study related to many phases of the research process, from philosophical issues to inferences drawn, and to the value of the study for consumers (Creswell, 2009). In this study legitimation was used as a way of obtaining findings and making inferences that are credible, trustworthy, dependable, transferable and/or confirmable. The researcher worked also along the lines of Denzin and Lincoln (1998), who refer to 'trustworthiness' as a more appropriate replacement for conventional constructs that pertain more to studies of a purely quantitative nature.

Methodological triangulation was also used to enable the researcher to search for convergence among multiple and different sources of information to form themes or categories in the study (Golafshani, 2003). Also, as one of the rationales for conducting mixed-methods research, triangulation was used aiming at seeking convergence and corroboration of results from these abovementioned methods. In this case, data collected from the survey were checked during interviews. Therefore, the study involved a 'cross-over tracks' approach, consisting of an iterative mixed-methods process such that emerging findings from one method helped to shape subsequent analyses (McMillan & Schumacher, 2010).

Establishment of additional credibility criteria for the study was further informed by the literature, where several researchers in the field of research methodology have made a claim that to establish reliability and validity during research procedures related to qualitative studies detracts from the subjective nature of the field of study. Here reliability was regarded as a fit between what the researcher records as data and what actually occurs in the natural setting being researched. Prior to the data collection phase further steps were undertaken in this regard. These included thorough attention to development of the data collection instruments and pilot testing of the questionnaire in order to ensure content validity. Furthermore, the range of criteria used in selecting teachers who participated in the study served to guarantee both population and ecological validities. However, to deal with the interpretive validity I simply relied only on the use of low-inference descriptors in the research report, because of the difficulty of obtaining participants' feedback given the distance between the research site (Rwanda) and the institution where the study was carried out (University of KwaZulu-Natal, Durban, South Africa).

CHAPTER FIVE

TEACHERS' UNDERSTANDING OF INQUIRY-BASED SCIENCE TEACHING

In the previous chapter a description of data collection methods and tools was given. These were chosen as they were considered most appropriate for gathering data that would provide answers to the research questions. Among other activities were interview transcription, coding, and identification of emerging themes and categories. The purpose of this chapter is to focus more specifically on providing answers to the first two research questions in the light of analysis of the data: (a) What is Rwandan O-level science teachers' understanding of IBST?; and (b) What attitudes do Rwandan O-level science teachers have towards the introduction of IBST into the curriculum? The term 'O level' also needs to be understood as 'lower secondary school', and therefore the two terms will be used interchangeably (while 'A level' refers to 'upper secondary school' in the Rwandan system).

Referring to what emerged from the data and the research questions, a number of empirical assertions and associated sub-assertions have been formulated, each being supported by information from the study's data as a way of organizing and conceptualizing the database that the study provides. Each assertion is presented along with supporting data in respect of the methodology adopted in this study, consisting of mixed research methods where, in a sequential way, a survey was followed by illuminating interviews. This is a style suggested by Gallagher and Tobin (1991), who argue that "it is appropriate to state the assertion and follow it with supporting data from the field notes or other source of data" (p. 91).

This chapter comprises three sections followed by a discussion of results. The first section is a description of the characteristics of the sample of teachers who participated in the study. This informs the reader about the origin of information (see Table 5.2) that was used to answer the research questions. The second section deals with the teachers' understanding of IBST. Section three is about teachers' attitudes towards the introduction of IBST and learning. Each section corresponds to a number of items from both the survey and interview, aiming at gaining as much information as possible concerning participants' details on the one hand and the two abovementioned research questions. Table 5.1 shows the link between the first two research questions and the sources of data from which assertions were generated.

Table 5. 1. Sources of data per section in Chapter Five

Sections	Sources of data		
	Survey (N=150)	Interviews (N=15)	Observation
5.1. Participants' characteristics and research site	Q1.1. (1-5); Q1.2. (1-6); Q1.3. (a-d)	Q I	
5.2. Teachers' understandings	Q 3.1.	Q VI	
5.3. Teachers' attitudes	Q 2.1. (1-9)	Q VI; XIII; XIV; XX & XXI	

5.1. PARTICIPANTS' CHARACTERISTICS AND THE RESEARCH SITE

This section aims at providing some details on the participants as context and background to the sections that follow. Knowing where data come from or how they are produced matters even for those who do not necessarily do research. Nieuwenhuis (2007) acknowledges the critical role of such a description, arguing that a most useful step in data processing as well as in the reporting of findings is to give a description of the study's participants, and that this should be as detailed as possible. This study used both quantitative and qualitative data collected in two sequential phases.

The first stage of data collection involved a survey of science teachers at lower secondary schools during the academic year 2010. A questionnaire was initially distributed to a sample of 200 teachers purposefully selected as described in Chapter Four. A total of 159 questionnaires were returned, but after checking and editing only 150 remained to be used as the study sample, giving a return rate of 75%. This high return rate can be attributed to personal visits by the researcher to respondents' schools and homes to retrieve the completed questionnaires. Nine questionnaires were eliminated due to a large number of the questions not being answered. In the forthcoming sections the capital letter N represents the complete sample of 150 teachers who responded, while *n* is used to represent the number of respondents to a particular item of a question.

Table 5.2 provides a description of participants in the survey phase of data collection by summarizing a range of their responses, including teaching experience in terms of number of years of teaching, their qualification and specialization as well as subjects taught. I disregarded personal information such as the names of teachers, names and physical location of schools or other identifying information to maintain anonymity.

Table 5. 2. Characteristics of respondents to the questionnaire

Characteristics		Number (N=150)	% (*)
Teaching experience	1 year	23	15
	]1- 5] years	65	43
	]5 -10] years	21	14
	>10 years	30	20
	No answer	11	7
Qualification	A2 (Secondary School Certificate)	22	15
	A1 (Diploma)	39	26
	A0 (Bachelor degree)	87	58
	No answer	2	2
Specialization	Biology-Chemistry Education (BCE)	63	42
	Physics-Chemistry Education (PCE)	14	9
	Math-Physics Education (MPE)	34	23
	Integrated Science Education (ISE)	5	3
	Other	20	13
	No answer	14	9
Subject taught	Biology	27	18
	Chemistry	25	17
	Physics	30	20
	Biology & Chemistry	30	20
	Physics & Math	18	12
	Physics & Chemistry	8	5
	Science with another subject	6	4
	No answer	6	4

(*) Due to rounding errors the total percentage is 100% \pm 1%

The respondents' teaching experience ranged from one to more than ten years. The majority of the sample can be considered relatively inexperienced, as nearly 60% had less than five years' teaching experience. The majority of teachers were qualified for teaching at lower secondary school, with Bachelor degrees and Diploma holders representing 58% and 26% respectively. About 15% with only a Secondary School Certificate (A2) do not qualify for teaching at secondary school. Depending on the subjects they have majored in during their pre-service training, teachers were qualified to teach various combinations of science

subjects. They mainly specialized in Biology- Chemistry Education (BCE) followed by Mathematics-Physics Education (MPE).

As for the subjects they were teaching, of the 144 teachers who provided information about subjects taught, the three science subjects were almost equally shared with a slight difference in favour of physics (18% taught biology, 17% chemistry and 20% physics). Others taught more than one subject - 20% taught biology and chemistry; 12% physics and mathematics; and about 5% physics and chemistry. The remaining 4% taught one or two science subjects together with a non-science subject, mainly including computer skills, geography and entrepreneurship, a subject recently introduced at each level of secondary school in Rwanda. However, in general the teachers' areas of specializations matched with the subjects they taught, as revealed from cross-tabulation. Of 60 BCE teachers, 21 taught Biology and 9 Chemistry, while 24 taught both Biology and Chemistry. Of the 14 PCE, five taught Chemistry, three Physics, one Biology and Chemistry, two Physics and Math and three Physics and Chemistry. Of the 32 MPE, 16 taught Physics and 12 both Math and Physics. It is important to note that in this study by science subjects I refer to the three subjects, namely Biology, Chemistry and Physics, and therefore a 'science teacher' in this study is anyone who teaches at least one of the three subjects, even when he or she may in addition be teaching one or more non-science subjects.

The qualification requirements to teach lower secondary science mentioned above are in respect of the Rwandan Teacher Development and Management policy, especially with regard to the current Rwandan teacher qualification framework. They do not necessarily imply competencies to answer questions about inquiry or to apply it as a teaching approach. In fact, these figures reflect the type of teachers in place and therefore responses from the 15% under-qualified teachers were not disregarded and were considered in this study. Unqualified teachers teach due to the shortage of qualified teachers in Rwanda, and are progressively being replaced as more qualified teachers graduate and enter the profession.

The relationship between the teachers' experience and their qualifications in the study sample can partially be explained by the context of the recent history of teacher training in Rwanda. Cross-tabulation between teaching experience and qualifications revealed that the largest group was teachers who had a Bachelor degree and were relatively new in the teaching profession. They had between two and five years of experience, as shown in Table

5.3. This general lack of experience in the sample can be explained by the fact that only one Higher Learning Institution of teacher training in Rwanda, the KIE, had been awarding degrees for only five years at the time the data were collected. This Institute was established in 1999 and produced the first cohort of graduates in 2004.

Table 5. 3. Years of teaching experience per qualification

Experience (years)	Qualification				Total
	A2 (unqualified)	A1 (diploma)	A0 (degree)	No answer	
1	6	2	15	0	23
2 – 5	6	11	47	1	65
6 -10	4	8	8	1	21
>10	5	14	11	0	30
No answer	1	4	6	0	11
Total	22	39	87	2	150

It would be expected that there would be more Diploma holders than Bachelor degrees, but this was not the case. The system trained teachers for the Diploma through a distance teaching programme (mentioned in Chapter Two), but this had not been functioning since 2005. Later in 2009 a similar programme was introduced, this time with two years of full-time training in colleges of education, but had not yet sent their first cohort of graduates into schools at the time data were collected. In addition, only one of the two colleges of education specializes in science teachers' training. Therefore it can be expected that the proportion of qualified science teachers with a Diploma will increase significantly in the next few years.

The schools that participating teachers came from were selected on the basis of a variety of criteria, including geographical location (whether rural or urban), the school statute (whether public, private or subsidized) and the streams offered. The need to include such a range of criteria for selection was based on the assumption that these characteristics may have in one way or another a certain impact on science teaching and learning, since the study was not aimed at isolating one particular type of school, but rather viewed the whole Rwandan educational system with particular reference to science at O level. For example, a rural school may have a different experience in implementing inquiry compared to an urban school. In other instances, a school with O level only would experience the science teaching and

learning differently from those hosting upper secondary school with science and/or other combinations. In many cases it was expected that schools with upper secondary science combinations were well established with more experienced science teachers, as well as more laboratories which may also serve O level. Also, good achievement of science schools at A level may stimulate the O level teaching and learning, and impact on the attitude toward science at the lower level. Table 5.4 provides more details about schools' characteristics and the teaching setting.

Table 5. 4. Characteristics of schools and teaching setting

Characteristics		No. of teachers	%
School statute	Private	57	38
	Public	57	38
	State subsidized	34	23
	Not reported	2	1
Streams	O level only	35	23
	O level with science stream only	34	23
	O level with non-science streams	24	16
	O level with science and non-science streams	53	35
	Not specified	4	3
Average class size	Less than 40	25	17
	Between 40 and 50	59	39
	More than 50	47	31
	Not reported	19	13
School location	Urban	64	43
	Rural	82	55
	Unspecified	4	2
Science teaching setting	In classroom	120	80
	In lab	14	9
	In lecture room	1	1
	Both in lab and in classroom	14	9
	Other setting	1	1

Table 5.4 also shows that over 80% of classes are generally very large with more than 40 learners. Over half of the respondents (55%) were from rural schools which was to be expected given that the majority of schools in Rwanda are rural, As for their statute, public and private schools are equally represented in number while the State-subsidized schools are few in number, representing the proportion found in reality.

Science resources such as laboratories were reported to be in short supply in the majority of schools. Table 5.5 shows the disparity in terms of laboratory availability per discipline.

Table 5. 5. Science laboratories availability (%)

Science laboratory	Lab availability		
	Yes	No	No answer
Biology	33	31	35
Chemistry	41	29	31
Physics	37	29	34
General purpose	26	35	39
Other setting	17	9	73

As it can be seen, slightly more than a third of teachers did not respond to the question about the availability of laboratories. The low response rate to this particular question may be interpreted as an indicator of a possible misunderstanding as to what to call a laboratory. Since minimum criteria were not defined in the questionnaire as to when to call something a laboratory, the researcher decided to leave it up to the respondents' judgement about what they would call a laboratory, as this may vary from place to place or school to school. For example, in some schools a room with a purpose-built laboratory, a storeroom, shelves or cupboard containing some apparatus and chemicals is considered as a science laboratory, while in others a multi-purpose room with just some desks and a few materials is also called a laboratory.

Recently (in 2010) efforts to improve the teaching of science subjects in general and at lower secondary school in particular have been boosted with the supply of science kits to over 2000 schools hosting the O level. A science kit is a movable set of science laboratory resources that can be used as an alternative in schools without a proper science laboratory. As a result of the lack of preset criteria as to what a science laboratory is, this kit could also be referred to as a science laboratory by some schools and not by others. Therefore, there is uncertainty as to what a science laboratory is, and these data are open to further investigation. My personal visits to schools also revealed this variety of interpretation. During those visits I personally checked the contents of kits, and felt that any lower secondary school that has at least the abovementioned science kit - if well used - in addition to an appropriate room

equipped with running water, electricity and a number of tables to accommodate all learners during a practical session, can be considered as having a science laboratory.

On the question about the science teaching setting, it was reported that science lessons take place mainly in the classroom (80% of participants), while very few (less than one-tenth) reported teaching science in laboratories. About the same percentage (10%) reported that their science teaching takes place both in classrooms and the laboratory.

Overall I believe that the teachers surveyed and schools they work in are reasonably representative of all Rwandan lower secondary science teachers. This group is made up of both rural and urban teachers, non-qualified and qualified in all combinations offered during their pre-service training. Schools they teach in cover all types of schools in Rwanda, as grouped based on the school statute criterion. Therefore, there is a heterogeneous distribution of characteristics such that information collected may reflect close to the reality that prevails in Rwanda lower secondary science schools.

In the second phase of data collection 15 science teachers were interviewed and in some cases observed teaching. These teachers were selected from among those who responded to the questionnaire, on the basis of similar criteria as used in selection of participants in the survey. Table 5.6 summarizes information related to participants interviewed and their respective schools. As it can be seen from this Table 5.6 the majority of teachers that were interviewed were qualified; most had majored in Biology and Chemistry and had less than six years of teaching experience. The schools where these teachers were based were also purposively chosen on the basis of the same range of criteria considered in the first phase of data generation in order to ensure that participants in the second phase were representative of the first group. It also can be seen from Table 5.6 that the teachers' characteristics were represented in almost the same proportions as in the main sample. Furthermore, some of those teachers who were interviewed offered the opportunity of observing their lessons. During observations the focus was to inquire about the context in which teaching science was taking place because before any lesson visit no prior arrangement was made to ask the teacher to set specifically an inquiry-based lesson. Therefore these data were not systematically analysed.

Table 5. 6. Characteristics of the sample of interviewees

Interviewees' characteristics		No. (N=15)
Gender	Male	11
	Female	4
Qualification	Bachelor degree (A0)	11
	Diploma (A1)	2
	Secondary School Certificate (A2)	1
	Others	1
Specialization	BCE	7
	ISE	2
	MPE	3
	PCE	1
	Others	2
Experience	1 year	1
	]1 – 5] years	9
	]5 – 10] years	3
	> 10 years	2
School's location	Urban	4
	Rural	9
	Semi-urban	2
School's statute	Public	7
	Subsidized	5
	Private	3

Participants in interviews constituted a representative sub-sample of the overall group, and were similar in terms of qualification, experience, schools' statute and location. Therefore I strongly believe that the second set of data are relevant for explaining and refining those from the first phase by exploring participants' views in more depth, and therefore contribute to increasing the validity of the study.

5.2. TEACHERS' UNDERSTANDINGS

This section comprises a discussion of the teachers' understanding of IBST. It constitutes an attempt to answer the first research question, which is about the science teachers' understandings of IBST. After analysis of the available data the following assertion and associated sub-assertions were made and supported by evidence from both the survey and interviews.

Assertion 1:

Teachers associate inquiry teaching with a number of common characteristics such as learner-centred teaching and practical work. However, a minority of teachers do not have accepted understandings of inquiry teaching.

This assertion was formulated based on data compiled from responses to an open-ended question in the questionnaire, where teachers were asked to describe what their understanding of IBST was (Q3.1, Appendix A) and additional details gathered by means of a similar probing question through interviews. Science teachers who responded to the questionnaire displayed varying understanding of the concept of IBST. They mainly provided very short descriptions. An attempt was made to analyse data from this question and responses were grouped into the following simple categories:

1. Practical work of some nature: Responses grouped under this code refer to learners doing practical work, carrying out experiments or some kind of hands-on activities;
2. Learner-centred activity: Refers to learners doing more work than the teacher and being actively involved in the learning process, or emphasis put on learners' active participation;
3. Learning by discovery: Learners working on their own and discovering new information based on their prior knowledge, but with some guidance;
4. The teacher as facilitator and guide: Where the teacher's role is reduced to providing guidance to learners rather than giving them all the information;
5. Doing research and self-study: Learners' participation by searching for information from various sources such as the library, Internet, school surroundings, etc.
6. Learners questioning: Learners' involvement by formulating questions to be answered through a number of specific steps, mostly associated with practical work in the form of investigation; and
7. Learning that is relevant to daily life and learners' interests: Learning for application in learners' daily experiences.

The frequencies of appearance of these categories are presented in Table 5.7.

Table 5. 7. Distribution of teachers' understanding of IBST

Teachers' characteristics of inquiry	Frequency	%
Practical work of some nature/ investigation	62	47
Learner-centred teaching	59	42
Learning by discovery	22	17
Teacher as facilitator and guide	19	14
Doing research	11	7
Questioning is central	5	5
Relevant to daily life and learners' interests	4	3
Don't know or not informed	13	9
Unrelated to teaching method	12	8
Total	207	152

As can be seen from this table, the total number of responses appears to be higher than the total number of respondents, because most of them associated with more than one aspect used for describing inquiry. Therefore if, for example, learning by discovery was associated with research, as in this response from a teacher: "Inquiry based science teaching means teaching science by doing research and let the learners to discovering the reality" (Teacher 23), it was reported both under the code "Doing research" and "Learning by discovery".

Responses from interviews corroborated those from the survey. Interviewed teachers displayed their understanding of IBST in a variety of ways, but provided more detailed understanding than did the survey. These responses were coded and are reported in Table 5.8. As in the survey, respondents suggested more than one characteristic to display his/her understanding, and as a result the total frequency of occurrence appears higher than the number of respondents.

Table 5. 8. Distribution of teachers' interview responses

Teachers' understandings of IBST	Teachers responding	Frequency
Learner-centred teaching/ involve learners in their learning process	5; 6; 8; 10; 11; 12; 14; 15	8
Teaching where learners work in a group under teacher's facilitation/ guidance/supervision.	5; 9; 11; 13; 14; 15	6
Teaching where learners carry out investigation and practical work of some nature	3; 6; 7; 12; 13	5
Teaching that involves learners in research following the scientific process	3; 6; 12; 14	4
Teaching that brings learners to discovery	1; 4; 10	3
Teaching for solving everyday problems and long life	1; 2	2
Not sure / confused	2; 7	2

While responses from interviews provided more detail as to the teachers' understanding of IBST, two sources displayed almost a similar understanding, and the data coding came up with the same categories. Despite some differences which might be associated with one's language, most teachers' understanding matched the description adopted in this study. From the two sources of data, teachers referred to the variations of the five features of inquiry teaching and learning (NRC, 2000), the expectations of the new Rwandan lower secondary school curriculum (MINEDUC, 2007b), and included a number of actions as suggested in IAP (2010) which all together constitute the lens through which inquiry was interpreted in this study. Thus the description provided in the NSES, the MINEDUC and the IAP, which refers to a variety of characteristics of inquiry, were mentioned by at least one teacher.

The following three sub-assertions are formulated based on the variety of teachers' understandings. They are discussed based on the survey findings and supported by the interview data.

Sub-assertion 1a: The most common characteristic of IBST is some form of activity involving practical work

Practical work of some nature was referred to as a main description of IBST. This was reported by nearly half (47%) of the teachers who answered the questionnaire. Here any form of demonstration, practical work, experiment, investigation, or hands-on activities was coded as involving practical work. For example, one teacher reported that “I understand it as a teaching by investigation, to teach by using the teaching materials i.e. by all means ensuring that the lesson is more practical than theoretical” (Teacher 45). In another example a teacher highlighted the practical aspect and the learner’s responsibility, and said that he understands it as “a teaching centred on the learner by providing him/her a chance of manipulating the material, of thinking and deciding on the topic to be studied” (Teacher 67). Practical work in some form was also associated with other aspects such as discovery, research and teachers’ facilitation. The following are examples:

The learner will be able to observe, to touch and to discover the scientific reality by means of scientific materials natural and manufactured, visible and operational. This facilitates the learning. (Teacher 86)

The learner manipulates, discovers and summarizes easily new notions which reinforces the understanding because the learner him/herself conducts the experience while the teacher is there as facilitator, talking less. (Teacher 48)

It can be noticed that these aspects all characterize IBST and learning, even though they are providing a partial description compared to what is proposed from both the literature and this study’s framework.

In a more detailed way, practical work in some form was reported through interviews as for describing their understanding of IBST. The practical aspect was depicted in many responses, where it was referred to as experiments or a scientific investigation including several activities. For example, this teacher said:

According to my understanding, inquiry-based science teaching is a teaching approach based on learners’ activities, that involves learners in their learning process through a number of activities such as asking questions, designing and carrying out an investigation, conducting experiment, collecting data, and presenting results based on evidence. Actually it is an approach that brings learners to work following the scientific process. (Interview NT/ASPEJ)

When inquiry teaching was associated with scientific investigation, details were provided as activities that learners get involved in, including attempts to answer specific question like scientists through a number of activities such as observing, asking questions, trying to find answers and explanations. As this teacher explained:

Ah! Inquiry-based science teaching is a method of teaching where the learners carry out investigations and then after carrying out those investigations they come up with the results and the teacher can help them to improve what they come up with. By using this approach learners are involved in a number of activities including posing questions on a particular phenomenon, attempting to answer those questions by providing evidences, trying to come up with explanations and then presenting these explanations to others... (Interview NP/MSS)

Similarly, the following example also shows an understanding of inquiry in terms of learners' activities, all highlighting the practical aspect of inquiry:

Well, actually I understand inquiry-based teaching as that teaching approach which emphasizes learners' hands-on activities. Among activities learners go through when learning science through inquiry are observation, posing questions and probing explanation based on scientific evidence, carrying out investigation, collecting information, measuring, interpreting results and communicating results. (Interview MD/TTCZ)

It seemed to me that when teachers were asked through the survey, practical aspects of inquiry and the learner-centred nature were most commonly mentioned. However, when probed for more details during interviews they moved around a more formal definition, associating practical work with a range of other aspects including discovery, learners doing scientific investigation, learners' active participation and learner doing research. It can be seen that interviews provided more detailed answers than the questionnaire, and it was therefore worthwhile combining the two methods of data collection. This description shows that practical work in its variety of forms is the characteristic most commonly associated with inquiry.

Sub-assertion 1b: Teachers associated learner-centred teaching and teachers acting as facilitators with inquiry-focused teaching

It wasn't surprising that IBST was associated with learner-centred teaching under teacher facilitation. In the recent curriculum reform there has been a lot of emphasis on this aspect as a necessary characteristic of successful inquiry in the classroom, which comes from a shift in the teacher's role from the "sage on the stage" to the "guide on the side" (Collier, Johnson, Nyberg & Lockwood, 2012), thus devoting to the teacher the role of key facilitator in the learning process. In this study IBST was also referred to as learner-centred teaching, and in many cases associated with other aspects but in particular with the teacher's facilitation and guidance. Data from both the survey and interviews provides sound examples. For example, the following definition suggests that IBST is teaching centred on the learner and which resorts to the practical, while the teacher is just a facilitator (Teacher 4). With an almost similar description, another teacher commented saying that IBST is teaching more centred on the learner, who becomes more responsible in the teaching and learning process while the teacher is the facilitator (Teacher 149).

In another instances three aspects were put together for describing IBST. For example, two teachers (Teachers 3 & 145) associate the teacher's facilitation with discovery and learner-centred teaching, as follows:

It is a teaching of science centred on the learner where the teacher lets learners work under his/her help, guidance until they reach themselves at the same conclusion of the lesson itself. (Teacher 3)

Inquiry-based science teaching takes into account all activities which help learners to discover and strengthen new concepts and ideas. It is a teaching and learning process centred on the learner. The teacher is a facilitator. (Teacher 145)

Sometimes the description included a number of activities showing the learner centrality of the process and the facilitation role of the teacher. For example, this teacher reported so saying that "the learner manipulates, discovers and summarizes easily new notions which reinforces the understanding because the learner him/herself conducts the experience while the teacher is there as facilitator, talking less" (Teacher 48).

Responses from interviews corroborated this understanding. The following two examples illustrate such convergence:

It is a learner-centred teaching approach where learners take active role in their learning process under the guidance of the teacher. The teacher is actually a facilitator or a guide. (Interview MD/TTCZ)

The way I understand the inquiry-based science teaching, eeh, it is a teaching approach that emphasizes on learners' active participation, where learners are fully involved in hands-on activities by being engaged into activities that bring them to acquire knowledge by their own but with the close guidance of the teacher. (Interview HJD/GSM2)

Another teacher used a metaphoric comparison to describe her understanding of IBST by associating the learners' active involvement with the discovery aspect of inquiry in the following words:

My understanding of inquiry-based science teaching is that it is a teaching approach that focuses on learners' active participation whereby they are involved in activities that lead them to discover or to answer questions they have formulated while observing a phenomenon. In that way, the teacher helps them and guides their work but does not just bring them all what they have to learn. I consider inquiry-based science teaching and learning like an interaction where the teacher does not bring a plate of food to learners instead helps them to search for their own food and show them how they should cook themselves. And then they will enjoy more that food than the one they are given by someone else. (Interview IMC/DBK)

The teacher's qualification would sometimes determine the degree of confidence in his or her understanding. For example, this A2 certificate holder claimed not to be sure whether his understanding was right, and did not feel confident in applying this teaching approach. However, he made an almost similar comment about his understanding as many of his colleagues:

I am not sure if my understanding is the right one. I understand it as a teaching approach that places learners at the centre of the process of teaching and learning and the teacher acts as a facilitator of the whole process. I however don't feel enough equipped to apply this while I think that the only way of getting learners fully involved in activities would be in a well equipped lab setting and with a good library. Even when I try to get them discussing in groups on a particular topic or phenomenon, I think that there might be some aspects of inquiry but I am not very confident to

claim that I really understand what is it about and how it really works. (Interview RS/ESC)

Even though this teacher expressed a lack of confidence in his understanding, he shares a similar understanding with many other colleagues.

As it can be seen, interviews supplemented the survey and provided more detailed information, justifying the reason for considering the mixed-methods approach. The following example constitutes a rich description as it expands the understanding to a full description of an inquiry-based science lesson, including the role played by both the teacher and learners:

I see it as a teaching approach based on learners' activities rather than centred on the teacher, known as the traditional 'chalk and talk' teaching approach or direct instruction. In the inquiry-based science teaching approach, learners take more responsibility of their learning process for being involved in well-designed activities while the teacher becomes their facilitator or their guide.

He goes on to describe the inquiry-based classroom:

The teacher sets the activity and instructions, for example, whether learners are going to work individually or in a group and depending on either case, he or she gives relevant and clear guidelines. Once on task, learners try to understand the problem they are given, they ask questions around the phenomenon being studied; they collect data and think about the way they would answer these questions. Depending on the nature of the task, they can sometimes design an experiment and execute it. Once they have results, they can discuss before drawing some conclusions. At the end of the lesson, they share their results with the whole class in the form of a presentation made by one group member representative. At any time they can call the teacher for help where needed and he/she guides them to avoid a waste of time when they are stuck. They can also be given a topic with some questions and go to search for information in books, but this requires more time. What I have experienced is that these kinds of activities work only when we have a double period or when they are going to be done over the weekend and be presented during the following class session. (Interview HA/EAN)

Looking at this quote it seems quite long, but illustrates a more detailed understanding of IBST which highlights comments about learners' involvement under the teacher's facilitation. The above description illustrates a teacher's view in supporting this sub-assertion

that contends that IBST is understood as learner-centred teaching with the teacher acting as facilitator.

Sub-assertion 1c: Some teachers do not have an understanding of inquiry that matches that of the curriculum or general community of educators

The analysis of teachers' responses about their understanding of IBST revealed that although the majority displayed different levels of understanding, this was not the case for all. Some gave answers unrelated to the question, as they may have misinterpreted the question, and others obviously had different ideas as to what inquiry was. From the survey a total of 25 responses were either off topic or not associated with any characteristics of inquiry as referred to in this study, which was framed from the NES (NRC, 2000), the Rwanda lower secondary school curriculum (MINEDUC, 2007b) and the IAP (2010). Among them, 12 responses were unrelated to any teaching method. In the following example, this teacher has not actually answered the question but seemingly appeared to be associating inquiry with laboratory work since the training toward practical aspects and laboratory materials supply were highlighted by saying that "the government should reinforce the new curriculum by increasing the training sessions on more practical aspects. Also, more equity in increasing the remuneration of teachers and supplying schools with lab materials and schools manuals" (Teacher 49).

In another example the teacher's response had as its focus resources, but it was difficult to understand the point being made as he referred to 'concretization', reporting that "it is important to put more effort in acquiring material resources in order to have a more comprehensive and efficient teaching that implies concretization" (Teacher 106).

From the remaining 13, one was not informed at all about inquiry-based science, while others had other views of inquiry which did not match any of the characteristics of inquiry. One teacher simply reported that "I am not informed about inquiry-based science teaching" (Teacher 36). These two other examples illustrate responses where teachers showed a lack of understanding:

Inquiry-based science teaching is the teaching method which makes the students to do well by moving from what they know to what they need to know. (Teacher 131)

According to my understanding, to teach science through inquiry is simply to collaborate with other teachers and learners with reference to curriculum. (Teacher 59)

This lack of understanding was also noticed in interviews, even though further probing questions revealed that some characteristics could be depicted. That was the case for teachers 2 and 7, who were reported to be not sure or confused, but when probed provided some meaningful descriptions. This teacher displayed difficulty in expressing herself and gave an unrelated response: “this approach, if for example I try to follow this curriculum that we were given, for me this curriculum is well organized” (Interview KE/KSS).

However, when probed to provide more details, she reported the following; supporting the assertion that practical work of some nature was associated with inquiry-based teaching:

For me I see that this approach of teaching will encourage learners to do experiments, if I can say, not to simply concentrate on reading theories, rather doing practicals and experiments. So what I can say is that this curriculum or the teaching approach is well organized. (Interview KE/KSS)

As for teacher 2, although the learners’ independent work under a teacher’s facilitation was mentioned, the response is a bit confusing and does not indicate an understanding of inquiry:

The inquiry-based science teaching, I suppose that it is a method that we use to help students to understand science, to work themselves helped by their teachers and at the end they will be able to solve or to increase the quality or the production and they can be able to find their job. (Interview NN/GSSBS)

The two last quotes show either a lack of understanding as to what IBST is or simply a misunderstanding of the related question, showing that some respondents do not hold views that correspond with any of the commonly accepted characteristics of inquiry.

5.3. TEACHERS’ ATTITUDES

The IBST approach has been perceived as a shift from the traditional memorization of facts and concepts through direct teaching as the main teaching strategy to inquiry-based

learning in which students are actively engaged using both science processes and critical thinking skills when they try to answer questions (Kubiek, 2005). In this study the second research question was about what attitudes teachers had towards the introduction of an inquiry-based approach in the new O-level science curriculum. It is acknowledged that the attitudes of teachers constitute an essential ingredient to curriculum change, in the sense that it may be ascertained that to change the curriculum requires changing the people who are directly involved in its implementation.

While the word ‘attitude’ means the individual’s prevailing tendency to respond favourably or unfavourably to an object, person or group of people, institutions or events (de Souza Barros & Elia, 1998), it is often used interchangeably with terms such as interest, value, motivation, and opinion. To find out what the teachers’ attitudes toward inquiry were, both the questionnaire and interviews were used. The questionnaire included a number of statements to which teachers were asked to express their degree of agreement. Some were about the change itself and others were more about the implementation of the new curriculum which has a significant inquiry component. During interviews respondents were directly asked some questions which probed their attitudes toward the introduction of inquiry in the new science curriculum. They were asked about their opinion whether there was a need for revising the curriculum, and whether they favoured the change or not. The analysis of data from the two sources produced the following assertion and associated sub-assertions.

Assertion 2:

In general, teachers were positive toward the introduction and the implementation of IBST. They agreed that there was a need to change. They were reasonably positive about their ability to implement the new curriculum and stated that the change has brought about improvements in their teaching and learning.

The teachers participating in this study were supportive of the introduction of IBST in the new revised curriculum. In the context of the present study and particularly with regard to the new curriculum, a requirement to focus on IBST was the main change. Therefore, reference by teachers to the change in the new curriculum was inferred to refer to the introduction of inquiry teaching. Thus, in this study the inquiry-based science curriculum and

new curriculum were used interchangeably. Respondents to the questionnaire were asked to indicate their level of agreement to a number of proposed statements in relation to the new science curriculum. The question was of scale-type items from 1 to 5, where 1= Strongly disagree (SD), 2= Disagree (D), 3= No opinion (NO), 4= Agree (A) and 5= Strongly Agree (SA). Responses were compiled and are presented in Table 5.9, and basic statistics including use of standard deviation in conjunction with the mean were carried out as the most important statistics in research allowing a better understanding of the data (McMillan & Schumacher, 2010). The data were treated as interval data because the items were Likert type items with five choices which could be assumed to have equal intervals between them. Welleman and Wilkinson (1993) argue that this assumption is acceptable where the items are likert type items and there are more than four choices. Thus means were calculated to aid analysis. However, a more conservative approach was followed with inferential statistics and only non-parametric Mann-Whitney was used (Jamieson, 2004 ; Pallant, 2007)

As it can be seen in Table 5.9, individual items on this question relate to a number of aspects of the new curriculum, such as the need for change (items 1 & 2), its implementation (items 5; 6; 7 & 8) and personal confidence and satisfaction (items 3 & 9). Item 4 is about a comparison between the new and the old curriculum, with particular reference to learner-centeredness. Table 5.9 shows teachers' percentage responses of agreement with the majority of items, and data from interviews revealed similar trends.

Table 5. 9. Teachers' opinions about the new science curriculum (%) (*)

Statements about the new curriculum and inquiry-based teaching	SA	A	NO	D	SD	M	SD
1. There was a need to change the old science curriculum	55	37	8	0	1	4.45	0.70
2. I was involved in the change process	18	22	23	15	20	3.03	1.40
3. I am fully confident in my ability to implement the new curriculum	45	42	11	3	0	4.29	0.77
4. The new curriculum is more learner-centred than the old one	58	35	5	1	0	4.51	0.65
5. The teaching conditions in my school are conducive for implementing IBST	16	41	13	23	6	3.38	1.18
6. The new science curriculum is easier to implement	18	45	16	20	1	3.59	1.03
7. The physical resources in my school enable me to implement the new curriculum effectively	16	36	18	25	5	3.33	1.16
8. Implementing the new curriculum requires me to do more preparation and work than I did before	39	36	10	9	5	3.94	1.16
9. I am satisfied that I am doing a good job at teaching the new curriculum	36	51	8	5	0	4.17	0.79

(*) rounding error of $\pm 1\%$

A look at the mean distribution and corresponding standard deviations also indicate strong agreement towards the need for change, being confident in their ability to implement the new curriculum, and the satisfaction of doing a good job when implementing the new curriculum. The data are analysed and discussed below in more detail and presented in three sub-assertions which together form the main assertion presented above (Assertion 2).

Sub-assertion 2a: Teachers agreed that there was a need to change from the old curriculum based on traditional teaching toward an inquiry-based curriculum

Items 1 and 4 of Q 2.1 were associated with the need to change and comparison of the old curriculum to the new inquiry-based curriculum. From Table 5.9 it can be seen that the majority of teachers agreed that there was a need to change the old curriculum to a new one which was more inquiry-oriented. This agreement was reported by more than 90% of participant teachers. They also largely agreed that new curriculum was learner-centred compared with the old one, with again 90% in agreement. Despite this strong agreement for changing the curriculum, a view was expressed that teachers were not sufficiently involved in the change process. Analysis of interview data also supported this view. All 15 teachers interviewed reported that there was a need for change, and were in favour for it. Those interviewed provided more detail, including the reasons behind their opinions, which ranged mainly from a number of benefits associated with the new curriculum to supporting a more learner-centred focus, to mere personal preference without a particular reason. In order of importance, the following were the most reported reasons:

- Five teachers pointed out the benefits that the new learner-centred curriculum provides for learners. For example, Teachers 5 and 6 reported the following:

Yes there was a need to change because in the old curriculum, learners were passive but in the new curriculum, learners talk, give their ideas and this helps them to better understand. When learners are actively involved in activities, it helps them to better understand and keep their knowledge for long time. (Interview MP/EFOTEK)

Yes there was really a need of change because by the past even when I was myself at school we used just to take notes and memorize everything and the teacher would always ask things that he/she gave us in our exercise books. That was the old curriculum. But now, in the new curriculum, it requires that learners actively participate, do activities, search for evidence and do experiments. Learners go beyond the simple memorization and see how the knowledge to go through in school relates to their daily life and can be used to understand more things that they come across in their homes. (Interview NT/ASPEJ)

- Four teachers motivated their opinion of the need of change with the fact that the inquiry-based approach has been tested elsewhere and has positive results, and is therefore

recommended by experts and also by the NCDC. For example, Teacher 11 illustrated this saying:

Yes I think that there was a need of change because actually the teaching and learning approach centred on learners is the most recommendable by many educationist experts. It had surely proved to be more efficient ... I think that the National Curriculum Development Centre was also inspired by experts in education to bring in that change. (Interview RS/ESC)

- Two teachers (8 & 15) reported that the need for change was due to the fact that the new curriculum enables learners to compete in the region in respect of globalization:

[...] I think that from that curriculum there was a need of having the new one which actually shifted from the teacher-centred methods towards learner-centred method because as you see, the world is running and is very active. So for our students to be able to do something, you know, let me say to compete with other students of the world or for the region like EAC [*East African Community*], we had to shift from the TCM to the LCM and this would help our students to better learn and understand what they are actually doing. (Interview DE/MGS)

I think that the change was needed because of the obvious development of teaching methods. Although I don't really use inquiry due to many circumstances, I know that it has brought good results in terms of teaching science wherever it was implemented. So, in our case, the curriculum designers have found that it was necessary to try new teaching approach so that we move with the world and adopt changes enabling us to be competitive in this world of globalization. (Interview HJD/GSM2)

- Two other teachers (1 & 2) just criticized the old curriculum and thus saw the need for change, saying respectively that the old one was such “the teacher was bringing everything and gives to students and sometimes was not aware if students have understood” (Interview KS/KSS) and “the teacher was like a lecturer who gives notes to learners who will just reproduce”. (Interview NN/GSSBS)
- Teacher 9 criticized the old curriculum for ignoring and disregarding the learners' knowledge, capabilities and role in their learning process, therefore advocating the need for change.
- Only two teachers (7 & 14) saw the need for change without giving reasons. The first teacher reported that “Yes, it was necessary that change takes place from a teaching centred on learner to the one centred on teacher. That is what I prefer also” (Interview

KE/KSS), while the second indicated that he was not originally convinced but after training to use the new curriculum he realized that there was a need for change:

Uuumh, for me there was a need of change and it is even obvious because the responsible of education, I mean the NCDC initiated the change which means they knew better than everyone its advantages. But after the training on the utilization of the new curriculum, that is when I mostly believed that there was really a need of change. (Interview HA/EAN)

It may seem strange that the number of persons who gave reasons for the need for change is higher than the number of people interviewed; in fact, when more than one reason was reported by an interviewee, both reasons were indicated under their corresponding category.

Further analysis looked at the need for change as reported by teachers across their categories of qualification and teaching experience. Cross-tabulation revealed that there was great agreement that there was a need for change, irrespective of the teacher's qualification, as shown in Table 5.10.

Table 5. 10. Degree of agreement for change per qualification (%)

Qualification	Need for change					Total
	SA	A	NO	D	SD	
A0	32	19	7	0	0	58
A1	12	13	1	0	0	26
A2	11	4	0	0	0	15
Not reported	0	1	0	0	0	1
Total	55	37	8	0	0	100

Furthermore, when data were aggregated and grouped into qualified and unqualified, the Mann-Whitney U test applied indicated that there was close to being statistically significant difference in views expressed between the different groups of qualified teachers ($U = 1065$, $p = .051$). There was no significant difference when applied to number of years of teaching experience, contrary to the assumption that novice teachers may be hesitant to teach using inquiry because of their inexperience in the classroom (such as a perceived lack of classroom control in the classroom practices). Thus the need for change was reported irrespective of the number of years of teaching experience. Overall, based on the above description and evidence from the data, it can be seen that teachers shared the view that there was a need for change towards the new inquiry-oriented curriculum.

Sub-assertion 2b: Teachers had mixed feelings about the new curriculum. Some were positive and confident about their ability to implement inquiry as required by the new curriculum; the most common reasons for positive views were associated with the perceived benefits of inquiry. Those who were not confident mainly reported, among other reasons, their lack of training and the poor conditions in schools

Extracts from Table 5.9 related to Q 2.1 of the questionnaire provide information about teachers' attitudes towards implementation of the new curriculum. About 86% of respondents to item 3 related to confidence in ability to implement the new curriculum, at least agreed that they were fully confident in their ability to implement it. However, they acknowledged that it requires more preparation and work than they did before, with about three-quarters (75%) at least agreeing with this statement. There was also a low agreement that teaching conditions in schools were conducive for implementing IBST (item 5) and that physical resources in schools enabled teachers to effectively implement the new curriculum (item 7), with respectively only 57% and 52% agreement, while about 30% disagreed. What seems to be contradictory was the strong confidence (86% agreement, item 3) and the overwhelming satisfaction in doing a good job (85% agreement, item 9) when teaching the new curriculum while conditions in schools were reported not to be conducive and schools reported as under-resourced.

One recurring theme that arose during interviews was the resource base of the school. It was found that there was a relationship between teachers' confidence and resources – teachers who had resources appeared to be more confident, and where they did not have resources they were concerned. Some schools were reported to be well equipped, enabling teaching through inquiry, while in others conditions were so poor that it was very difficult to implement the inquiry approach. Only three of the 15 teachers interviewed were satisfied with their school conditions and thought they make easier and possible for implementation of inquiry in their classrooms. Six found conditions to be good and another six described them as either poor or very poor and therefore not conducive at all. In this latter case, teachers' ability to implement inquiry teaching might be compromised. The following two quotes describe schools where conditions enabled easy implementation of an inquiry-based curriculum:

This school is a little bit advanced. So I go quickly because all materials are there, our library is there, our lab is there, even the Internet room is there. So we implement it easily, it is easy for me because I help learners to go there, I give them the topic and they go there to check and after they give the results. (Interview MA/BSoS)

I personally have no problem because I was trained for it and the school has the minimum required resources, and we can borrow some from the G.S. [*this is neighbouring school called G.S. Notre Dame d'Afrique*] ... So I think that the conditions are conducive to implement the new curriculum because in addition all students are boarding, so they can continue discussing or work during the free study hours. (Interview HA/EAN)

On the other hand, very poor conditions at school make implementation of the new curriculum impossible, compromising the teacher's confidence:

It is not easy at all. This school doesn't have required conditions enabling one to be efficient in implementing this new curriculum. This new curriculum is more activities oriented than it was in the past where the focus was put on the content. And without required material, we cannot carry out all activities. Also learners cannot do their own research since there is no library, not even talk about Internet. The only resource available is the good sense of the teacher who does not know much as well ... (Interview NT/ASPEJ)

In another instance lack of confidence was associated with other factors, including time needed to implement inquiry and the class size:

Apart from what I have said, that it requires more time and that we have big classes with a shortage of materials, to be honest I can't claim that I am fully confident in using this approach. Sometimes you can try it and find yourself leading the lesson instead of leaving the place to the learners. (Interview MMJ/ESS)

Another teacher indicated that lack of confidence in implementation was due to the lack of training in the inquiry method during initial teacher education:

For me, I studied at KIE. We had science subjects and subject teaching methods and we went through teaching practice but we didn't really focus on inquiry. Though we were told about active pedagogy centred on learners' activities, we were not explicitly trained at using inquiry teaching approach. (Interview IMC/DBK)

It can be seen that both the survey and interviews revealed mixed feelings with regard to confidence in implementing the new curriculum. As for the reasons behind this, they reported a range of them, discussed in the section about factors influencing teachers' practices with regard to IBST.

After the survey and in respect of the study's design, I felt that data obtained required deeper probing, and I asked more questions through the interviews, including the reasons behind the positive attitudes displayed toward inquiry. Teachers were asked about what they considered the main features of the new curriculum compared to the old one. Data revealed that all 15 teachers who were interviewed acknowledged that the new science curriculum had many features which could be grouped under themes including structure, benefits it provides, emphasis and accompanying resources. Highlighting a favourable attitude towards this new curriculum, they pointed out some positive aspects of it by comparing it to the old one. In this regard one science teacher reported the following:

You can say that they are different. I can say that there are many things that are good because when you are applying this method proposed in the new curriculum students can understand well what you are teaching and I can say that they can apply what they have learnt in their everyday life. Again the socialization, when they are working in group, there is this behaviour of collaboration. There is a good relationship in class.
(Interview KS/KSS)

Another teacher highlighted the learning aspect embedded within the new curriculum, at the same time claiming that it can only be achieved once conditions allowing its implementation are all met:

I have already said it, the old curriculum was promoting mere memorization with less applications. But the new one, when conditions allow its implementation learners end up being able to solve many problems they encounter in their everyday lives like purifying drinking water, awareness of protecting environment, and to discuss scientifically on different issues. (Interview NT/ASPEJ)

The mixed feelings about confidence in implementing inquiry were also depicted in another account that acknowledged inquiry as a good teaching method, but where the teacher confessed not using it due to a personal lack of confidence:

I am not really sure with myself. However my view together with my little understanding is that inquiry doesn't result necessarily in better achievement in tests but is a best way of teaching science because to claim that one has learnt well is not synonymous with getting high marks. One can get good marks just after memorizing, depending on how he/she was assessed, and forget a few days or weeks later what he/she has learnt. But learning through inquiry is life-long learning and what is learnt through this way is for later use and can be applied and retrieved for solving own problem. So my view is that it is a best way of teaching science, the better learners'

understanding and high achievement may come in as a result of good teaching approach. (Interview RS/ESC)

Similarly, the following teacher supplemented his predecessor's ideas, reporting the benefits of inquiry-based teaching but also expressing discomfort for not practicing what he says, which again illustrates the well-documented gap between the intended and the enacted curriculum:

I think that inquiry may result in more learners understanding and therefore can lead to better achievement on tests, depending of course of the way learners are assessed. In fact while discussing, investigating, creating and discovering with their peers, they can easily interact with the environment they are exposed to and this is the core of a meaningful learning that better applies for science. This is how I view things but I am not comfortable because I don't actually practice what I am saying. (Interview HJD/GSM2)

Some teachers indicated that their satisfaction with implementing the new inquiry-based science curriculum was because it was nicely structured and had good support materials (referring mainly to learners' textbooks and teaching guides). The following teacher's quote illustrates this satisfaction:

Fundamentally this new curriculum, I found it more structured and rich than the old one. For example, the old one was more content-based with too much theory, less references and without specifying activities related to each section or chapter. This new one is more searched if I can say that. It is more activity-based. For each section, activities are detailed and the apparatus whenever relevant are described. Also the references, where to get information are provided. But the most interesting with the new curriculum is that we are now provided with textbooks for learners and teaching guides for the three science subjects and for each year of [*tronc commun*] O level. (Interview HA/EAN)

Further details about teachers' attitudes towards the introduction of the IBST approach were sought, and teachers were asked what they considered as benefits of inquiry, and their possible choice between using inquiry and traditional teaching approaches, even when the two may lead to similar results on tests. They were also asked to motivate their choice. All 15 teachers interviewed expressed their preference toward inquiry-based teaching at the expense of the traditional teaching approach. They indicated a range of reasons that motivate their choice, all focusing on the advantages associated with inquiry-based teaching. As for the perceived benefits of inquiry, responses yielded evidence that may justify their preference

toward inquiry-based teaching and the expressed positive attitude. It was revealed that the most common benefit reported was that inquiry is a good method of teaching science. The distribution of interview responses is seen in Table 5.11.

Table 5. 11. Teachers' views about benefits of inquiry

Perceived benefits of inquiry	Teachers responding	Frequency
Good method of teaching science	2; 3; 4; 5; 7; 8; 9; 10; 11; 13; 14	11
Increases learners' understanding/ more understanding	1; 2; 4; 6; 10; 11; 12; 14; 15	9
Increases pass rate/ good marks on tests and exams	1; 2; 4; 6; 8; 9; 10; 12; 15	9
Develops learners' positive attitudes toward science	1; 13	2
Promotes learners' personal development	13	1

It can be seen that many of these perceived benefits of inquiry were sometimes combined into a single response, and as result the total of frequencies in Table 5.11 is far higher than the number of people interviewed. For example, in the following quote the aspect of understanding was reported together with a way of teaching science:

My opinion is that inquiry results in more learners' understanding. As a best way of teaching about science, yes it is but it shouldn't be used alone, it should be mixed with other approaches to be more effective. Actually, when one learns through hands-on activity as one aspect of inquiry, the knowledge acquired lasts forever and can be used later and in various areas. Inquiry is actually the way of doing science. (Interview MMJ/ESS)

In another instance, the benefit of resulting in good marks on tests and exams was reported together with that of it being a good teaching method for promoting thinking and problem solving skills:

My opinion is that it is the best way of teaching science despite problems related to its implementation. It enables learners to actively take part in their learning process and therefore can at the same time earn good marks on tests and exams. It improves learners' thinking skills and the science that they learn through inquiry serves them in solving problems they encounter in their daily experience. So, if all schools were able to solve problems related to teaching resources, I would suggest that all science teachers embark on the journey of teaching science through inquiry. (Interview DE/MGS)

Another combination encompasses a number of perceived advantages that learners would gain from inquiry:

[...] I think that it most results in more learners' understanding and brings into learners positive attitude towards science. And again when it leads students to like science, the results on tests or exams will also increase as well. (Interview KS/KSS)

In the same way, another teacher had a feeling that an inquiry-based approach is a best way of teaching science if associated with other teaching approaches as for promoting learners' personal development, and further provided reasons why it is not always used in many schools:

I am personally convinced that it is the best way of teaching science but would work better if mixed with other approaches. I say that because it was proved that the traditional way of teaching used to be limited at the lower level of Bloom's taxonomy and consisted of promoting just memorization. But through inquiry, learners develop a kind of personality and learn how to think and to try alternatives when attempting to solve a problem. Also when learners learn by doing they can find ways of applying what they have learnt in other situations. You can see that even during their free time they continue discussing issues they were involved in classroom activities for they had had their hands-on and were given opportunity to discuss. However, the approach is not always used in our schools due to a number of reasons including the lack of confidence of teachers to implement it, the lack of materials and the general poor conditions in many of schools. (Interview MD/TTCZ)

The above description shows that teachers had mixed feeling about the new curriculum, and therefore it can be anticipated that its implementation would also be marked by differences. These will be further discussed under the theme about factors influencing teachers' current practices with regard to implementation of IBST.

Sub-assertion 2c: Teachers indicated that teaching through inquiry has resulted in improvement of a number of aspects of teaching and learning, such as learners' increased participation and collaboration with classmates

This sub-assertion was based on data from the two sequential phases of data collection. In the survey teachers were asked to rate a number of areas that may have improved since they started using the inquiry approach in their teaching (see Q3.4). Responses were on a scale from 1= Least improved to 5= Much improved, and were summarized in Table 5.12. Responses for item 8 ('Other aspects') of the question were disregarded and treated as missing values due to a very low response rate (23%). This may be due to the open-endedness of the item as respondents were asked to give and rank any other aspect they felt has improved.

Table 5. 12. Teachers' views about areas of improvement as a result of using inquiry (%)

Areas that have improved	1	2	3	4	5	M	SD
1. Learners' participation in classroom	2	3	12	31	52	4.27	0.94
2. Learners' collaboration	3	3	11	35	47	4.21	0.98
3. Learners' attitudes towards science	0	3	20	37	38	4.09	0.88
4. Teachers' classroom management skills	2	4	15	41	35	4.05	0.93
5. Learners' achievement on tests	3	7	23	37	27	3.81	1.01
6. Classroom discipline	6	8	24	33	27	3.68	1.14
7. Time spent learning science at home	3	11	23	28	24	3.67	1.09

A close look at the mean distributions shows that teachers had a feeling that there was a significant improvement in some areas proposed in the abovementioned question. Analysis of means and standard deviations indicates that 'learners' participation in classroom' (M = 4.27, SD = 0.94) and 'learners collaboration' (M = 4.21, SD = 0.98) have significantly improved, while 'the amount of time spent learning at home' comes last after 'classroom discipline' as least improved. However, in general there was a noticeable improvement in all of the seven areas.

When interviewed, teachers mentioned additional aspects of science teaching and learning that have improved as a result of incorporating inquiry in their teaching. The most common aspect that has improved was “the learners’ attitudes towards science”, as reported 14 times by the 15 teachers who were interviewed, followed by the “learning skills” for learners, reported 10 times and “teaching skills” for teachers, reported eight times. Other aspects of teaching and learning that were pointed out included a number of observable behaviours such as learners’ curiosity, inquisitiveness, and communication skills. The following quotes illustrate these views:

The learners’ attitude towards sciences has also improved because we now see them applying science in their daily experience. (Interview NP/ MSS)

I can say that learners enjoy more science than before. Their participation has improved, they are now able to talk and to express their ideas in science and see science in terms of what they can do with it at home. (Interview NT/ASPEJ)

What I have noticed is that it builds more confidence in learners when they discuss some science issues. Even when you give them a test you can see that they can explain things in their own words and give examples. Also when they work in groups, you can see that they care for each other and the weakest learners are also given room to participate in discussion and bring in his/her ideas. Another thing is that it seems to increase their curiosity because they ask more questions when involved in activities than in the traditional lessons. (Interview MMJ/ESS)

Keeping in mind the pragmatic sequential mixed-methods design of this study, I probed more deeply in the interviews and found that teachers reported a combination of several areas that have improved, both on the side of the teachers and the learners. This teacher gave the following example:

I think that there are some. Let me give few examples. The enrolment rate in science streams has increased over the last three years. I can say that the attitude towards science for the majority of young learners has somehow changed positively. Even girls who in the past didn’t like science are now showing more interest. Learners’ collaboration and communication also seem to have improved especially among those in S3 where they are no longer shy to discuss. Maybe it is my view, I find my learners becoming more curious and more inquisitive, asking why this and that and so on. Me too, I benefit because I have learnt about a new teaching approach which I was not familiar with before. Also my ways of managing my classroom have improved because I can take time to listen to learners. (Interview HA/EAN)

Another teacher pointed out a variety of areas that have significantly changed, even though he acknowledged not using inquiry often enough. He attributed the improvement to other factors associated with the new curriculum, and most importantly the resources recently supplied to schools:

Unfortunately I don't use inquiry too often. But some areas have so far improved not only due to the use of this approach but also due to the new curriculum itself and very recently with the accompanying textbooks that were distributed in schools. I can say that learners enjoy more science than before. Their participation has improved, they are now able to talk and to express their ideas in science and see science in terms of what they can do with it at home. And globally, learners score better marks than before. (Interview NT/ASPEJ)

It was further reported that the use of inquiry in teaching science offered teachers an opportunity of learning and improving some teaching skills. In the following excerpt, a teacher points out some lessons and areas of improvement he gained when attempting teaching through inquiry. A close look shows that he saw inquiry in terms of practicals, which matches the assertion about teachers' understanding of IBST:

Thank you. Actually, the side that has been improved is the practicals. When I am teaching by using this, by engaging my students in their learning process and give them some practicals, I am also learning. By giving them these practicals, by helping them and reading about practicals, I feel like, I learn, eeh I learn about it. And also I learn about the use of new materials. Another side that has so far improved is the fabrication of some materials because when I realize that I cannot find a material and try to use improvisation, I think that at that time I learn a lot about the fabrication of materials. (Interview DE/MGS)

It is clear that teachers express their positive view of change and feel ready to implement it, and there is evidence from their responses that they have actually begun introduce inquiry. The positive attitude toward the change seems to have played an important role. As a result, according to the teachers, a number of aspects of teaching and learning have improved both for teachers and learners. Although learners' participation in the classroom and collaboration were ranked to be the most improved, they were combined with other aspects such as learners' attitudes toward science, communication skills and practical work. Overall, teachers are reporting many positives from the introduction of inquiry in their teaching.

Sub-assertion 2d: Teachers considered the current trend toward inquiry teaching as positive and holding promise for the future of science education

It is often recommended that when collecting data from people, whether by means of questionnaire or interview, to consider toward the end having an open question where the respondents are free to make any further comment in connection with the topic being studied. In both data collection activities this was observed, and participants were asked whether they had any other comment about the teaching and learning of science at O level in Rwanda. The above assertion was constructed from responses to Q 6.2 on the questionnaire and the corresponding last question of the interview.

Of the 150 teachers who completed the questionnaire, 23% did not make any comment while 3% made unclear comments. The remainder made a variety of comments. The most common comment was about the need to supply schools with resources, including laboratories, materials, equipment and textbooks, which was seen as the major enabler for teaching science in general and implementing an inquiry-based teaching approach in particular. This was reported 53 times in various comments (this is not the number of teachers who commented since some combined a number of aspects in a single comment). The second issue of concern was the crucial need for in-service training as a way to improve the quality of science teaching and learning at O level with an emphasis on inquiry. This was reported 40 times. A significant number of teachers also commented that teaching through inquiry is very demanding and requires more time. Together with a general claim that they had a heavy workload, they felt that reviewing the teachers' workloads downward (13 times) and increasing the number of hours for teaching science (three times) would help to deal with the issue of time required to do inquiry. The issue of large class size was also reported as a major concern that needs particular attention if one hopes to really teach using an inquiry approach (six times). The motivation of science teachers was highlighted in various comments, especially in terms of an incentive bonus, salary increase, accommodation in the vicinity of schools and allowances. An incentive bonus for motivating teachers was reported nine times and allowances four times. Another comment made only three times but also valuable was about training principals or head teachers in science so that they could be more responsive to science teachers' grievances specific to science subjects. It was pointed out by a few teachers

that some principals who do not have a science background may not pay enough attention to science teachers' demands, which differ from those for other subjects.

Interviews supported the analysis of data from this question and raised additional issues. Almost all teachers interviewed were optimistic about the near future of the teaching and learning of science at O level in Rwanda. Supporting claims included responses to a question about how participant teachers saw the future of teaching and learning of science in Rwanda, supplemented by the closing question about any other comments on science teaching at O level in Rwanda. Eleven of the 15 who responded to the question expressed a positive view about the future of science teaching and learning at O level in Rwanda. The two following excerpts from teachers' responses illustrate this:

I am a bit satisfied with the current trends even though much still to be done. The future seems to be promising because the government is committed rather than ever before to improve the area of science and technology. This can be seen through clear government policies with regards to science education and various interventions of some projects (BTC, JICA, SMASSE,) in science teaching and learning, but all this still not sufficient for all schools. (Interview NT/ASPEJ)

It is on the good way; much has been so far achieved but also much still needs to be done mostly in the areas already mentioned. But what is more positive is that science is among the government's priorities and therefore there is hope that the current trend will never go backwards. (Interview IMC/DBK)

However, while valuing concrete actions that have already been done, they acknowledged challenges still to be faced, especially with regard to the obvious problems associated with the introduction of the free nine years of basic education that considerably increased the number of lower secondary schools countrywide:

I think that it is on a good way and many positive changes had already taken place even though there is still a long way to go. There is a great improvement in terms of quantity but the quality is still a challenge. A lot of money is needed to equip all the new schools known as Nine Years Basic Education. So many new schools are ill-equipped and this would negatively impact on science teaching and learning and therefore learners' performance. However there is a noticeable willing of the government and all stakeholders of improving the area of science education in general. (RS/ESC Interview)

Science teaching and learning in Rwanda is still facing many challenges. Like now there is a very big number of new schools running O level but which do not have the minimum requirements for teaching science, while at the end of this level learners will write the same national exam. I know the government has goodwill and is committed to improve the quality of science education at all levels, but still has a long way to go. It is a big challenge. But the steps that have so far been made allow one to hope for the best. For example the recent distribution of science kits and textbooks in schools is a great achievement, but more efforts need to be done. (Interview HA/EAN)

Commenting on the overall state of science teaching and learning in Rwanda during the interviews, many aspects were pointed out. The main issues highlighted were related to current problems that the Rwandan education system is facing, such as the gap between what they described as “good schools” and “poor schools” in terms of infrastructure, equipment and resources and teachers’ attrition. Others highlighted issues that need to be attended to by various education system stakeholders in order to enhance the quality of education in general with a particular focus on science. The issue associated with the recent development of creating a number of new schools with O level but which still need to be equipped with both human and material resources was raised again and again:

Too many schools with O level were created these last two years, but they are underequipped, understaffed, and therefore are not providing the expected results in term of quality of teaching and learning. Well, it enabled us to increase the enrolment rate at secondary school but much effort needs really to be put in the Nine Years Basic Education programme. (Interview IMC/DBK)

The recent distribution of science textbooks and science kits seems to be greatly welcomed in many poor schools as one of the most important achievements towards improvement of science teaching and learning:

The only comment I can make is that science in Rwanda is seen as the top priority within the education system. With the recent distribution of textbooks and science kits in all schools, there is a sign that there is an improvement being made, but it is still a drop in the ocean. (Interview RS/ESC)

Acknowledging the positive steps that have been made so far, another teacher first praised what has been achieved but also highlighted a number of problems, such as lack of basic infrastructure, big class size and teachers’ attrition:

There are many positive aspects that have been achieved while other areas need particular attention with regard to science teaching and learning at O level. For example the recent distribution of science textbooks in English and science kits will contribute a lot to teaching science at O level. Also schools are now increasingly getting qualified science teachers since KIE has started train them. However, when you look at conditions under which some schools operate, you find that we still have a long way to go. Some schools are very poor, overcrowded and far from any infrastructure such as water or electricity. I think that over all this, strategies of teachers' retention should be put in place because it seems also to be a problem, especially in rural schools. (Interview HJD/GSM)

To sum up, teachers made a variety of comments where a number of issues were raised. Some were general comments while others were specifically in relation to inquiry. All comments in the interview were also raised by at least one or more teachers in the survey. The following issues were raised by teachers in interviews:

- The gap between good and poor schools: This was reported by five teachers and highlighted a big gap between well-established schools and poor schools in terms of infrastructure and resources. This issue is not a new phenomenon in the Rwandan educational system but was recently exacerbated by a great disproportion between new schools and corresponding accompanying resources. The same gap exists in all types of schools, irrespective of the location:

[...] But because of the big number of new schools with O level, these Nine Years Basic Education, there is a very big gap between these schools and the old ones that were established many years ago ... Much needs to be done to bridge this gap because at the end of the *tronc commun*[O level] all learners have to sit for the same national exam regardless the state of school they are from. (Interview MD/TTCZ)

- The issue of lack of resources was reported in six comments from teachers, and seems to be directly linked to the previous one. It has been strongly highlighted as not only impacting on the implementation of inquiry but on the whole teaching of science, especially related to the learners' achievement:

A comment I can make is about what I have already said when you can have very poor schools having nothing and good schools with everything while all learners have to write the same exam at the end of O level. How can a student who had never seen an electric light, for example, compete with those who have Internet, laboratories or libraries? It is unfair, I think that those responsible for education should think and look at ways of addressing these issues. In my school, I don't complain a lot but I know that the situation is even worse in so many schools. (Interview MMJ/ESS)

- Issues associated with assessment and with the need for in-service training were each reported three times. To illustrate:

Uum, ok. What I would suggest, eeh for me when I consider for example the exam that is given to learners at the end of the year, I notice that they ask questions that go beyond the learners' level, learners' capacity. That is what I have seen. I would suggest that those who set exams refer to the curriculum because when we teach we follow the curriculum. So, it may be good if they set questions based on the curriculum. (Interview KE/KSS)

I suggest the supervision. Maybe supervisors or inspectors both at national level and district level should go to schools and visit teachers when they are teaching and see what they are doing and advise where it is necessary. And number two; we need training of O-level science teachers and this training would help them to understand the meaning of this and follow what is said in the curriculum because even the evaluation is based on the curriculum. (Interview NP/MSS)

Other issues pointed out through different comments were reported just once each, and referred to class size, salary and other incentive increases, heavy workload and increasing hours of teaching science. All issues reported in this particular sub-section are also referred to in section 6.3 of Chapter Six, especially in the section dealing with factors influencing teachers' practices and suggested ways to better implement IBST.

5.4. COMMENTARY

In this chapter an attempt was made to answer the first two research questions. The first issue of concern in the study was to find out the understanding that teachers have in connection with science and teaching in Rwanda. In any research it is essential to find out and ensure that participants have the relevant understanding of the core concept of the study as a basis for seeking further information. In this particular study it is even more appropriate, since it is well documented that teachers are unclear about the meaning of inquiry (Wee, Shepardson, Fast & Harbor, 2007) while they are the key agents of its implementation. Furthermore, Anderson (2002) contends that inquiry teaching is defined differently by different researchers and has many meanings, and that even when used in a particular field of science education it has multiple manifestations, making it difficult to clearly define (Anderson, 2007). Referring to the NSES, he argues that the lack of a precise operational definition of inquiry teaching would lead to many and varied images of inquiry teaching from teachers.

Empirical data from the study indicated that teachers who had views of IBST attempted to define it by providing a number of its characteristics. Their understanding can be interpreted with reference to the five essential features of classroom inquiry and their variations (NRC, 2000) in many instances, and the activities of both teachers and learners that take place in every inquiry-based science lesson (IAP, 2010, pp. 9-10), as well as the Rwandan revised O-level science curriculum as part of the framework of this study. Although they did not all provide similar definitions, many responses included a number of characteristics found within the descriptions provided in the abovementioned references. They did not, however, mention the type and degree of inquiry (Wenning, 2005a), even though it will later be seen that their practices fall under the most structured and guided inquiry. Except those who show a complete lack of understanding, such as those mentioned above, all others have understandings that have a place in the broad description of IBST and learning as framed in this study. However, from the variety of understandings displayed, it was possible to anticipate the way this teaching approach would be implemented in the classroom. It may be assumed that implementation would not follow the same pattern of activities.

It was found that teachers associate inquiry teaching with a number of characteristics, such as a learner-centred teaching approach with much focus on practical work. However, not all participants displayed the same understanding, and the understandings of some were far from an acceptable description as provided in the literature or as framed in this study. This is to be expected as the literature itself supports that there is a lack of a concrete set of examples of inquiry, showing that teachers do not have a common understanding of the science inquiry teaching method (Barrow, 2006; Bybee, 2000; Kerlin, McDonald & Kelly, 2009). In this regard Smithenry (2010) also acknowledged that no single definition of classroom inquiry exists, despite the substantial amount of writings that attempt to answer questions such as what inquiry is or what it looks like in practice. Even the NSES do not set clear definitions of what constitutes inquiry in various contexts and see it as a teaching approach, as process skills and as content (Anderson, 2007). This variety of understanding associated with the difficulty to give a concise description of inquiry teaching has shaped this study, as teachers also displayed the same lack of a single definition of inquiry teaching and rather associated it with a number of characteristics related to teachers' and learners' actions in a classroom.

The facilitating role of the teacher was also frequently associated with inquiry-based teaching. It was further found that teachers had a positive attitude towards the introduction and implementation of IBST, and acknowledged that the change toward the new inquiry-oriented curriculum has brought about an improvement in their science teaching and learning. This is also supported by the literature. Besides many resources required for supporting inquiry, students should benefit from the expertise of their teachers, who in turn should provide guidance to students at all stages of the inquiry process and at all levels of inquiry (Eastwell, 2007). The role of the teacher in this study was found to be that of facilitator, but nuances embedded in the data indicated that this role covers many of the aspects of the teachers' role pointed out by Crawford (2000), including that of "motivator, diagnostician, guide, innovator, experimenter, modeller, mentor, collaborator and learner" (p. 931-932).

It can be noticed that the survey on its own would not provide a real picture of what the teachers' understanding of IBST was. Respondents just gave very short sentences with limited information. However, when details were probed through interviews, they were more detailed and showed that they knew a lot, more enabling one to interpret data and findings with regard to the proposed framework. It is important to value interviews over a survey

when one expects more detail on a studied phenomenon. Approaching the study from a pragmatic perspective using mixed methods proved to be a valuable approach and added much depth to understanding of teachers' views which a single method would not have achieved.

A thorough analysis of teachers' responses about their understanding of IBST revealed that their various descriptions have many elements that are provided in the NRC's (2000) definition of inquiry. All elements of the definition of inquiry, such as making observations, posing questions, planning and carrying out an investigation, searching information, gathering, analysing and interpreting data and communicating results were highlighted in the majority of teachers' responses about their understanding of IBST. It was also found that information about understanding from the questionnaire was slightly different to that from the interviews. While the first focused on what IBST is, the second was that teachers reported on their understanding of inquiry in terms of what takes place in an inquiry-oriented classroom. These findings are not surprising since the literature acknowledges that inquiry teaching is defined differently not only among different researchers but also among educators. Anderson (2002) highlighted this point, arguing that the literature on inquiry tends to lack precise definitions and rather rely on examples. The same reality would be expected with teachers in this study, especially considering that not only is inquiry a very new concept in Rwandan educational science, but more importantly, as shown in chapter two, the teaching of science in Rwanda is still at an earlier stage than many other developing countries. Furthermore, it would be expected from an interpretive perspective that teachers have different views, for they come from different background, qualifications, and context. From the interpretivist perspective used to analyse teachers' views, it was not expected to find everyone understanding inquiry the same way e.g. as expounded by policy documents. The initial and in-service science teacher training should try to bring them as closer as possible to similar understandings but from the researcher's perspective they could never be exactly the same.

The second issue of concern was related to teachers' attitudes towards introduction of the IBST approach. Teachers were globally positive about the change that introduced inquiry into the new curriculum. Reasons for their preference of an inquiry teaching approach over the traditional approach included a number of benefits associated with inquiry which are

likely to be supported by the literature (Anderson, 2002; Marsha, 2000; Oates, 2002; Songer, Lee & McDonald, 2003 & Walker, 2007). For example, even though it was reported in the study by Cobern, Schuster, Adams, Applegate, Skjold, Undreiu, Loving, & Gobert (2010) that “good direct and inquiry instruction led to similar understanding of science concepts and principles in comparable times”, it was on the other hand acknowledged that “inquiry-based instruction potentially offers significant advantages for science education” (p. 11).

Furthermore, there is a huge amount of empirical support about the benefits of teaching science through inquiry (Abd-El-Khalick, Boujaoué, Duschl, Lederman, Hosftein, Niaz, Treagust & Tuan, 2004, Anderson, 2002; Hmelo-Silver, Duncan & Chinn, 2006), and teachers involved in the present study shared most of these views, whether they applied the approach or claimed not to be sure whether they implemented it or not. What the study revealed is that these benefits concern both learners and teachers, as stated by Linn (2000) when he argues that when teachers and learners utilize inquiry and exhibit the processes of thinking that inquiry promotes, they find science more accessible, making thinking more visible, they learn from each other and promote lifelong science learning and discovery.

When a change is envisaged within a curriculum or a new approach introduced, official documents are often too ambitious with educationally sound ideas, but when it comes to implementation it appears much slower and more difficult than anticipated (Rogan & Grayson, 2003). Resulting from this inherent difficulty of implementing a change, the fundamental structure of schools today shows little difference from those of the past, despite long-term efforts to reform education (Cresdee, 2002). In the process of curriculum change, whether involving small changes easily assimilated with teachers' former practices or more substantial changes requiring overcoming teachers' prior beliefs, teachers' attitudes play an essential role. This critical role of the teacher in embracing change was discussed two decades ago during major reform in science education, when Bybee (1993) reported:

I remain convinced that the decisive component in reforming science education is the classroom teacher. We certainly need books, reports, and recommendations for new policies, and we need new materials, projects, and programs. However, unless classroom teachers move beyond the status quo in science teaching, the reform will falter and eventually fail. (p. 144)

In this study the change in question was quite substantial, consisting of responding to and implementing a new teaching approach that was introduced into the curriculum. To some

extent the change requires a conceptual shift in the way teachers think about teaching. Promising was that, teachers participating in this study displayed a positive attitude towards the introduction of the change and were confident in implementing it. Although many teachers do acknowledge the need for change, they face growing expectations and declining resources. While traditional views about curriculum implementation assume that failure is the fault of teachers, this idea is still prevalent, ignoring the support that they deserve. Implementation success can only be operationalised by changes in teachers' practices and attitudes (Cresdee, 2002).

From the above it will be noted that some areas were reported to have corroborated findings from the literature. For example, Gibson and Chase (2002) in their study on the impact of an inquiry-based programme on middle school students' attitude toward science highlighted a number of studies that have found that "inquiry-based science activities have positive effects on students' science achievement, cognitive development, science process skills, laboratory skills, and understanding of science knowledge as a whole" (p. 694). In this study teachers indicated that teaching through inquiry has resulted in improvement in a number of aspects of teaching and learning, such as learners' classroom participation and collaboration, attitudes toward science, practical work as one of the components of inquiry, as well as results on tests and exams. This corroborates Gibson and Chase's (2002) report, which identified a number of other studies indicating that students who learn science using an inquiry approach score higher on science achievement tests and develop more positive attitudes towards science. In the present study, however, the focus was not on analysing the learners' results on tests or the change in attitude, but was limited to what participant teachers reported as areas of improvement as a result of implementing an inquiry teaching approach. These dimensions will be subject to further and separate investigations.

The next chapter, in an attempt to answer the next and last three questions, discusses issues including the teachers' practices and activities they are engaged in with regard to inquiry teaching, factors influencing their practices, as well what they suggest as ways for better implementation of IBST.

CHAPTER SIX

TEACHERS' IMPLEMENTATION OF INQUIRY-BASED SCIENCE TEACHING

In the previous chapter analysis of data produced answers to the first two research questions about teachers' understanding of and attitudes towards IBST in Rwanda. Participant teachers associated inquiry teaching with a number of common characteristics, mainly learner-centred and practical work. However, there were also a few teachers whose understanding was not similar to any accepted by the science education community. It was found that teachers generally said they were positive towards the introduction and implementation of inquiry-based teaching. The present chapter is about the implementation of IBST. Implementation here encompasses teachers' practices, influencing factors and ways of improvement.

This chapter is divided into three sections corresponding to each of the three specific research questions. The first section analyses the teachers' practices with regard to IBST and relates to research question three (What classroom activities do these teachers engage in with regard to IBST?). The second is an analysis of factors that teachers report as influencing those practices and attempts to answer research question four (Why do these teachers respond to IBST in the way they do?). The third and last section is about teachers' suggested ways for better implementation of IBST associated with research question five (Based on their current practices, how do they think IBST could be better implemented?).

Table 6. 1. Sources of data to answer research questions

Research questions	Sources of data		
	Survey questionnaire	Interviews	Observation
Research question 3	Q 1.3a-d & Q 4.1 (1-10)	Q II; V; VII; VIII & XII	Classroom / school observations
Research question 4	Q 5.1 (1-10)	Q III; XII; XIII & XV	
Research question 5	Q 6.1 (1-7), Q 3.8	Q XVIII; XIX & XXI	

Table 6.1 shows the three research questions with corresponding sources of data used to answer them. The corresponding assertions and associated sub-assertions are related to activities participant teachers reported being involved in when implementing inquiry-based teaching and the factors that influenced their practices as well as strategies teachers thought could be adopted for better implementation of IBST.

6.1. INQUIRY-BASED SCIENCE TEACHERS' PRACTICES

This section discusses the teachers' practices and activities with regard to implementing IBST. The lens through which inquiry was seen in this study was presented in Chapter Three. Reference is made to the NRC (2000) and the Rwanda O-level curriculum which sees inquiry mainly as practical-oriented in the form of scientific investigation, which can be located on Wenning's (2005b, 2011) continuum of inquiry based on the criteria of both teachers' guidance and learners' responsibility. Ideally inquiry activity is seen as involving questioning, planning, implementing or carrying out the plan, explaining and concluding, reporting and applying. An inquiry-based lesson would be more or less open according to Wenning, depending on the balance between the teacher's and the learners' responsibilities in accomplishing these activities. In the context of this study it was expected to see teachers' and learners' activities fitting within this description. The following assertion and associated sub-assertions were empirically formulated in an attempt to answer the research question about teaching and learning activities that take place when teachers make use of an inquiry approach in their science classrooms. In respect of the methodological design adopted in this study, findings are informed by data from both the survey and the interviews supplemented by information obtained from personal observation. In many cases data from these sources corroborated each other, but also sometimes contradicted.

Assertion 3:

According to the teachers, traditional classroom activities were more frequently used than inquiry-based activities. However, when teachers include inquiry in their teaching they generally follow a specific order of activities. These activities indicate a more structured than open-ended type of inquiry

When implementing the change brought into the O-level science curriculum, teachers would also be expected to change their usual practices. It is therefore within this perspective that one section of the survey questionnaire was about the ranking of the frequency of use of a number of teaching activities when teaching science. This assertion is based on the analysis of the data dealing particularly with: (a) the variety of teaching methods used and related activities, and (b) the pattern of activities teachers engage in when making use of inquiry. Two sub-assertions arose, which when taken together form the above main assertion.

Sub-assertion 3a: In their daily teaching, teachers report that they use traditional classroom activities more often than activities associated with inquiry

This sub-assertion was constructed based on data from the survey and the interviews as well as the classroom observations (see Table 6.1). In the survey teachers were asked to rank a set of teaching activities in terms of how frequently they were used, on a scale of 1 to 10 where 1 indicated used most frequently and 10 that this was a least used activity. The purpose was to see the extent to which teachers were using inquiry-type activities such as investigation, discussion and projects, i.e. those that allowed learners more involvement, as opposed to more traditional type activities such as teacher demonstration and copywork. The descriptions for each activity were provided in the questionnaire (see Appendix A, Q4.1).

In the interviews the focus was on probing for more detail by asking them to describe their daily teaching of science, how they go about implementing the new science curriculum and the methods that they see as most efficient as well as the frequency of using inquiry in their daily teaching. The classroom observations focused on any other interesting aspects that could be noted and the extent to which inquiry-related activities were taking place in a classroom. During the school visits 10 lessons of teachers who were interviewed were observed. The researcher visits were informal in nature, looking for evidence of the practices teachers reported by observing some lessons, looking at the textbooks which were used and whenever possible visiting the school laboratories. This observation aimed at a better understanding of teachers' practices, particularly with regard to the conditions under which their teaching takes place.

Teachers reported that they used the different activities, but to different degrees. A summary of their ranking of frequency of use is given in Table 6.2, showing the percentages of respondents with regard to each.

Table 6. 2. Ranking of use of teaching and learning activities (%) (*)

T & L activities	1	2	3	4	5	6	7	8	9	10
Teacher demonstration	26	15	19	9	11	5	4	6	2	2
Exercises	13	23	18	14	10	9	7	3	2	0
Copywork	22	21	15	5	8	5	4	7	7	6
Homework and tests	5	7	13	21	26	14	7	3	3	1
Carrying out practical in lab	17	14	7	16	7	11	8	6	5	8
Group discussion	5	7	13	9	10	12	21	17	3	3
Investigation	4	7	8	8	12	11	18	19	9	8
Direct teaching	19	6	6	6	6	9	3	8	15	21
Fieldtrips	5	3	3	3	5	5	11	7	20	37
Project	3	1	3	4	5	6	10	19	21	29

(*) rounding error of $\pm 1\%$

The overall picture from Table 6.2 shows that activities such as teacher demonstration, copywork and exercises were ranked as being most frequent. Projects and fieldtrips appear to be least frequently used. Teachers were divided on the use of “direct teaching”, with almost as many teachers using it often as those who used it rarely, showing a bimodal distribution.

Because the data provided are ordinal in nature, means cannot be computed to determine rank order. Consequently, examination of the table of data or cumulative counts was used. The top three were considered as most frequent activities, i.e. if a teacher ranked them in the top three, they were considered as frequently used. If in the bottom three, they were considered least frequently used. Those in the middle were not ranked as most or least frequently used. For example, teacher demonstration had 60% putting it in the top three groups, while investigation was in the bottom three with only 19% indicating that they used it more often than other activities. Similarly, exercises and copywork respectively had 54% and 58% in the top three most frequently used. The bimodal distribution of direct teaching is seen, with 31% in the top three and 44% the bottom three. Considering the bottom three (8, 9, 10) it is obvious that projects at 69% and fieldtrips at 64% were least used by the majority of

teachers. The other activities in the middle grouping were all used frequently but did not fall into either most or least frequent. Based on this analysis of responses it can be seen that traditional classroom activities were more frequently used than inquiry-oriented activities.

Further analysis focused on differences between various groups of teachers, such as their qualifications, experience or school's location. Given the ordinal nature of these data, only non-parametric statistics could be used. For this purpose, the Mann-Whitney U statistic test (Field, 2005) was used. It was found that in most cases no patterns of difference between the categories of qualification were identified. After recoding the qualification under two groups, qualified for A0 and A1 together and non-qualified for A2, it was found that there was a statistically significant difference between the two groups for their ranking of 'direct teaching' ($U = 1017, p = .044$). An examination of the distribution of responses showed that unqualified teachers tended to rank direct teaching as not frequently used, while the qualified teachers were divided with some ranking it as frequently used and some as least frequent.

The frequency of use of different teaching activities was also very similar across the categories of teachers' experience and school location, irrespective of number of years of teaching and school location (urban or rural). In the case of least frequently used activities the use of fieldtrips was significantly different across the category of years of experience ($U = 1711, p = .016$). Although 'fieldtrip' in general was the least used, it was even less frequent among teachers with little experience. As for 'investigation', there was a significant statistical difference between rural and urban teachers ($U = 2147, p = .021$), with rural teachers ranking it as more frequently used than urban teachers. From the above, the few differences observed do not contradict the predominance of traditional over the more inquiry-oriented activities for any particular group of teachers.

While the survey data provided some insight into frequency of use of some activities, the purpose of the interview was to probe for more detail. In general, analysis of the interviews supported the assertion that the teachers generally used traditional activities more frequently than inquiry-based activities. In the interviews teachers were asked to describe their daily teaching of science and to report the method that seemed to work best for them. Responses from interviews indicated that teachers used a combination of several activities, some more frequently than others, similar to responses in Table 6.2. Some activities they used tended to be more inquiry-oriented while others were more traditional.

The teachers used a number of different activities, including some inquiry-related activities. The following two quotes from interviewed teachers illustrate the combination of teaching methods:

So about my daily teaching I do mix a number teaching methods ranged from explanation, demonstration and exercises, laboratory experiments and learners carrying out investigations in small groups. Very few times we do organize some fieldtrips. (Interview HA/EAN)

As recommended in the new curriculum, I mostly focus on learners' activities. So I give them a work or a topic to work on like carrying out a sort of investigation on a given topic. They can sometimes work individually but I encourage teamwork so the brilliant learners can help the weaker ones. (Interview NT/ASPEJ)

The combination of teaching strategies includes practical work that seems to take the form of verification while some inquiry-oriented activities tend to be more structured. For example, in the following teacher's response the structured form of inquiry is evident in that the teacher provides the question to be investigated and instructions, while the practical tends to consist of verification though including most of investigation steps:

There are numerous activities in which learners get involved. For example, in Biology when we are studying plants, learners are the ones who collect samples of plants that we would use in class. Then they work in group and carry out a kind of investigation on a basis of clear instructions I give to them. Another example is when they go in lab to perform some experiments aimed at verifying some facts that were already discussed in class. There, I bring a question or help them to formulate it and they try to answer. Then they do a number of things such observing, collecting data, measuring, manipulating variables, draw conclusions, and write down a report and present results to their colleagues. (Interview DE/MGS)

The teaching activities were also combined but differ depending on setting, whether taking place in the classroom, the laboratory or the field. The following illustrates this difference based on teaching setting, having with the demonstration and verification aspect in common:

When we are in class, we go mostly in the traditional teaching method with emphasis put on science concepts. Here I explain concepts with support of examples. Learners are less active in such lesson, though they do participate by asking and answering questions. They also give examples from their daily experience that shows that they can integrate the concept learnt in class in their everyday life. In lab, that it is where students do actively participate. They carry out experiments. For example, they dissect a sample of animal like a rabbit when we study the anatomy, they describe by

observing different parts and functioning of the digestive system of the given sample. On field, learners do observation that allows them to formulate a question, collect a number of data and information; and once back in class they present to their peers what they have learnt from the field. Then with the help of the teachers we draw some conclusions and do some activities of assessment. (Interview KD/SAR)

On the other hand, some teachers did not use inquiry. For example, the following teacher seemed to be very traditionally oriented and her teaching had less to do with inquiry. In her response she started off as if she was speaking on behalf of her other colleagues, but ended up reporting her personal practices:

What we do as teachers is to plan our lessons, we do our preparation and make notes to give to students and then we go in class to teach what we have so far prepared. Once in classroom, one tries to follow steps of direct teaching [*exposé*], if I can say that. (Interview KE/KSS)

The following two quotes also illustrate a non-inquiry practice:

Well, about teaching method, I can say that interrogative method is the most efficient because through this method the teacher speaks and the learners speak too. I can say that the interrogative method is the best. But I also use demonstration. (Interview MP/EFOTEK)

In my daily teaching I try my best to make sure that my learners are having interest in the subjects I am teaching. What I do, I try to focus on the curriculum, prepare my lessons on a regular basis, trying to make use of examples that learners are familiar with and that get meaning in their daily life. For example, when we are studying physics concepts, I try to relate them to the learners' daily experience and highlight their applications. Because of the lack of teaching aids, the teaching is mainly theory and copywork supplemented with exercises and homework. (Interview RS/ESC)

It can be seen that details obtained from interviews clearly indicate that some teachers carry out inquiry and others do not. All this shows that there was an attempt to implement some inquiry in their daily teaching by the majority of those who were interviewed. However, traditional activities were still predominant, and even among those that seem to be inquiry-related, learners followed instructions from their teachers or answered questions designed by the teacher, leaving less room for learners to formulate their own question and design their way of answering it. Even the practical work appeared to be oriented toward demonstration of concepts and verification rather than questioning and generating explanation based on evidence.

In the survey further information was obtained about teachers' practices. These activities would be associated with inquiry practices, as many indicated more involvement by learners than expected in traditional teaching. In this regard teachers were asked how often a number of practices associated with inquiry teaching and learning were taking place (Q 4.2). Responses were coded on a scale from 1 to 5, where 1= Always, 2 = Frequently, 3 = Sometimes, 4 = Rarely and 5 = Never (Table 6.3).

Table 6. 3. Frequency of occurrence of some teaching practices

Teaching practices	Frequency of occurrence (%)					Mean	SD
	Always	Frequently	Sometimes	Rarely	Never		
1. Teacher ensures equal participation of all learners	57	38	5	0	0	1.49	0.60
2. Learners search for additional information	36	37	21	5	1	1.99	0.10
3. Teacher decides alone on topic to be studied	38	32	16	8	6	2.12	1.17
4. Teacher also learns from learners	22	30	42	5	1	2.33	0.98
5. Lessons set to the pace of slowest learners	14	23	40	17	6	2.79	1.08
6. Focus on O-level national examination	14	22	32	19	13	2.96	1.23
7. Focus on completing the syllabus only	17	19	26	15	24	3.10	1.40
8. Teacher lets learners decide on topic to be studied	3	10	29	25	34	3.78	1.10

For the purpose of descriptive analysis, responses were aggregated into 'Often', grouping together 'Always' and 'Frequently' and 'Seldom' for 'Rarely' and 'Never' grouped together. From this table it can be seen that during their teaching they always ensure equal participation of all learners (95%). Although teachers often decide alone on the topic to be studied (70%), while the practice is seldom for learners (59%), they more often (73%) ask learners to search for additional information on topics discussed in classroom. Furthermore,

slightly more than half of the teachers reported often learning from their learners (52%), while almost the same proportion did so sometimes (42%).

As to how often teachers focus on the national examination, on covering all topics as assigned in the syllabus as well as on setting the pace of lessons to the slowest learners, teachers had mixed feelings. These mixed feelings were more pronounced for focusing on the full coverage of the whole syllabus (36% often and 39% seldom) with an almost bimodal distribution and a highest value of standard deviation ($SD = 1.40$). Similarly, 36% and 32% focused on the O-level national examination often and seldom respectively, while about a third of teachers did so sometimes. This is a reality, because O-level performance is often assessed based on learners' achievement in the national examination. With that aim in mind, teachers tend to put more effort into covering all topics presented in the curriculum in preparation for that level's exit examination, which may be a limiting factor of using inquiry – which is often criticized by teachers as being too time-consuming.

Given that the items were 'Likert-type' with five choices on a scale (Jamieson, 2004), some basic statistics could be used in the analysis. A close look at the mean distribution revealed similar trends and led to some statistics across different categories of teachers participating in this study, related to teachers' qualifications, experience, school location, etc. Analysis showed few differences. The Mann-Whitney U test only found the items 'teacher ensures equal participation of all students' and 'teachers learn from learners' to be significantly different across the categories of qualification (item 1: $U = 1047$, $p = .047$ and item 4: $U = 1012$, $p = .033$). The higher qualified teachers reported learning less from learners, while unqualified teachers reported striving more than the qualified teachers to ensure that all learners participated equally.

Additional information which was not asked in the survey but which was considered to provide more details about teachers' practices was sought by means of interviews. Teachers were asked how often they make use of inquiry in their teaching. Responses indicated that the use of inquiry ranged from none to being always used, and reasons were varying (discussed in a later section dealing with factors influencing teachers' practices). As in the survey, it was found that interviewed teachers were also divided with regard to frequency of use of the inquiry teaching approach. Of the 15 teachers who were interviewed, one reported using inquiry always, five often and four sometimes. Five other teachers

reported rarely or never using inquiry. The following example of a teacher's response during interview illustrates more frequent use of inquiry:

Uuhm, maybe I may say that every time I am teaching. Every time when I am planning I do use this inquiry teaching method because I feel like it is very helpful for students though maybe I can fail sometimes to get some materials and some products. But I feel when I am planning for my classes, I do think about it and maybe I cannot say that I use it 100% but I use it, let me say, about 80%. (Interview DE/MGS)

This response is from a teacher who reported seldom using inquiry, but this could be linked to limited understanding of what inquiry-based teaching is:

Uuuhm ... I told you that I don't really use inquiry; even something I think might be related to inquiry, I am not sure, probably just one of its aspects. I can't really say that I use inquiry. (Interview HJD/GSM2)

From those who never used inquiry, one made it clear that direct teaching comes first but that on occasion he used practical work based on observation:

Eah, what I mostly use is exposé. More often I expose (direct teaching) and then practicals and observations are just used few times. But at the moment, what I can add is that very recently we have acquired a number of textbooks that help us to make use of observation. So, exposé comes in first position, observation comes second and lastly the practical. That is what I can say. (Interview ME/KSS)

Among those interviewed, of teachers who reported using inquiry just sometimes, one tried to estimate the percentage of teaching time allocated to it:

Although it is very profitable and has many other features, I don't use it [*inquiry*] all the time because it requires more time and this new curriculum is more condensed, it is big and difficult to be covered in the allocated time. Maybe if I can try to estimate the percentage of time I use it, it is about 40% of the time allocated to my teaching. (Interview NP/MSS)

From the above analysis of interview responses, it can be seen that teachers strove to shift from learner-centred towards teacher-centred methods, but the former are still being used. Where claims of using inquiry were made, it seemed that just some aspects of inquiry took place, still with greater teacher direction. However, what appeared to be common was a combination of theory and practical. Observation was also reported as more often used as a basis of inquiry-related activities.

Furthermore it was reported that despite a desire to involve learners in practical work, and despite the need to mix several teaching methods, some activities such as experiments would take place only depending on availability of required materials:

My teaching is actually guided by the curriculum but my own initiative in terms of trying to improvise some teaching aids contributes a lot in enhancing the quality of my daily teaching and learning. I make use of a variety of teaching methods depending on the topic of the day. Sometimes I can teach the content but I try to involve more and more students in practical activities, including conducting some experiments when the materials allow it, and sometimes they can do some personal research on a particular topic. (Interview MMJ/ESS)

Data from the survey and interviews converged to inform that teachers are divided with regard to their practices and the activities they carry out. It was found that inquiry-based activities were taking place mostly in combination with traditional classroom activities. The teacher's leading role still appears to be predominant. They used a combination of several teaching strategies. Regardless of qualifications, experience or the location of the school they were based in, traditional teaching strategies were still more common practice. However, there was a sign that teachers had the will to change their daily teaching practices to embrace inquiry-based teaching, because the large majority (including those who do not use inquiry) often reported that they would prefer to use it at the expense of traditional direct teaching – even where the two approaches may lead to similar results on tests, as discussed in section 5.2.

Sub-assertion 3b: When teachers engaged in inquiry teaching, it tended to be of a more structured and closed form

Given the responses to the survey, it was found that teachers did attempt to engage in some form of inquiry activities. Interviews were used in order to find out more information about the type or format of these inquiry activities. Teachers were asked to describe the main steps or activities they went through when using inquiry in their classroom. Analysis of responses from interviews showed common activities or stages in the inquiry planned, and a certain sequence of activities. The role of the teacher is still predominant. Responses were

coded and are reported in Table 6.4. As can be seen, of 15 teachers who were interviewed, only 10 attempted to answer the question. Three (teachers 2, 3 and 7) seemingly didn't understand the question and provided unrelated responses. It was felt that this indicated a lack of understanding and further probing was not done. Two other teachers (11 & 15) were simply not asked because it was a follow-up question which was only relevant to those who had previously reported using inquiry.

Table 6. 4. Summary of patterns of activities when using inquiry

Teachers	Introduction / Brainstorming	Find out topic, Question or Task	Give instructions	Experiment/ Group work / Discussion	Coaching / Supervision	Presentation to peers	Conclusion / Synthesis/ Notes	Unrelated to inquiry practices
	T&L	T & L	T	L	T	L	T & L	T
1 (KS/KSS)		x	x	x		x	x	
2 (NN/GSSBS)								x
3 (NP/MSS)								x
4 (MA/BSoS)			x	x		x	x	
5 (MP/EFOTEK)		x	x		x	x	x	
6 (NT/ASPEJ)	x	x	x	x	x	x	x	
7 (KE/KSS)								
8 (DE/MGS)	x	x	x	x				x
9 (KD/SAR)			x	x		x	x	
10 (IMC/DBK)		x	x	x	x	x	x	x
11 (RS/ESC)								
12 (HA/EAN)		x		x	x	x	x	
13 (MD/TTC)	x	x	x	x	x	x	x	
14 (MMJ/ESS)	x	x		x	x		x	
15 (HJD/GSM2)								
	4	8	8	9	6	8	9	4

T= teacher, L= learners, T& L= both teacher and learners.

From Table 6.4 it can be seen that although learners were involved in inquiry-oriented activities such as doing experiments, group work, and presentation of results, they were still directed by the teacher who provided instructions to be followed and then coached and supervised the activities. Both learners and teachers participated in introducing the lesson through brainstorming and formulating the question or the topic as well as in the synthesis and concluding the lesson. Data from the same table also reveal that when teachers reported that they use inquiry strategies in their classroom, they tended to follow the same pattern of

activities that fit into the inquiry framework, generally describing a process that went from posing a question to communicating results. Even though some would skip one or more steps, the general trend seems to include some of the most common steps of an inquiry investigation. The two following teachers describe their practices whereby questions are set by the teacher and the learners are given instructions to follow:

When I am in my classroom, first I give the students the topic, next I give them instructions about what they are going to do, and then put them in small groups. Once in those groups, they try to work on the topic. After they come together and discuss what they have seen and if, for example, the first group presents one part of the topic, the second does another and so on. At the end of the time you can find that they have brought each and everything from the topic. They take notes that come from these discussions. (Interview KS/KSS)

[...] when it is an inquiry-based lesson, the main steps we go through are in the following sequence: I set the lesson objectives as usually. I then determine the activity with clear instructions. Then I present the task to learners who work in groups. The setting can be the normal classroom, the lab or any other place like out of the class. That is why I said that it depends on the lesson. Learners work under my supervision. Here again the work can consist of many activities such as observing, measuring, taking information, trying variables and write down results or answers to questions. After, if we have time each group can be asked to present to colleagues what they have done. The lesson normally ends with a summary that synthesizes the product of the learning activity. Sometimes, further questions can be generated at this stage and can be given to learners as another activity or homework or assessment. It always depends on the prevailing circumstances. (Interview IMC/DBK)

Another teacher went on to distinguish specific activities for both the teacher and learners, as it is known that the inquiry classroom engages teacher and learners with different degrees of involvement; the teacher shifts from full to partial involvement while learners progressively move from passive to fully active participation in their learning process. It was highlighted that the type of activity would require and determine a specific setting:

Actually, when I use inquiry teaching strategies in my classroom, there are specific activities I go through and others that are for learners. As a teacher, it is my responsibility of planning the lesson. I set the activity and specify the instructions where required. After a short brainstorming, learners are put in small groups and given the task and I clarify instructions. Learners work in group under my supervision. Here the work can consist of activities such as observing, measuring, taking information, trying variables and writing down results or answering questions.

Depending of the type of activity, this can be done whether in class, in lab or in any other setting. When they are fully engaged in discussion I move around and intervene time to time whenever necessary. Once they have finished, each group can design a group representative whose task is to present the results to the whole class. Again the discussion can take place before conclusions are drawn and a summary made highlighting the major points from the whole activity. (Interview MD/TTC)

From the above description it can be seen that teachers are still doing normal traditional activities. When attempting to integrate inquiry in their practices, depending on the topic and circumstances, they include some practical work which takes the form of a very structured investigation or inquiry in which the teacher sets the task and then gives instructions to follow. The study indicated that the most commonly followed sequence of activities was as follows:

- Introduction/brainstorming
- Topic
- Task/question/activity
- Instructions
- Group work/experiment
- Supervision
- Presentation
- Conclusion/notes/ synthesis.

Some teachers would skip one or more steps from the sequence. The data from the few classroom observations supported this assertion, and it was found that even those which included some aspects of inquiry were either confirmatory practical-based activities or guided investigations. In total 10 lessons were observed: four Biology, two Chemistry and three Physics, and each year of the three years of lower secondary school was seen at least twice. Two of the 10 lessons were the purely teacher-centred type, but others included some aspects of inquiry. What was most common was the active participation of learners in different settings, but instructions were given by the teachers confirming the predominance of structured inquiry when it does take place. These data were just for context illustration and were not systematically analysed.

6.2. FACTORS INFLUENCING TEACHERS' PRACTICES

Designing a curriculum is one thing and implementing it is another. When it is about a change brought into the science curriculum, the implementation becomes even more complex as it involves an amalgam of both intrinsic and extrinsic factors (Lewthwaite, 2006), some fostering implementation while others inhibit it. In the South African context Rogan and Grayson (2003) acknowledged that implementation may appear more difficult than expected during the curriculum design phase: "Whilst the policy documents themselves contain many visionary and educationally sound ideas, the implementation of these ideas is proving to be much slower and more difficult than anticipated" (p. 1172).

In the previous section teachers' reports on their current practices when implementing IBST were discussed. This section is all about factors influencing these practices. Research has demonstrated that the ability of individuals to change their teaching practices is dictated to a large degree by a variety of factors (e.g. Cheng, 1994; Ekiz, 2004). These factors can be either internal or external and can have either a positive or negative influence. Internal factors include the teachers' training, beliefs about the change, teaching experience, and predisposition to embracing the requirements of the change in their daily practices. External factors include, among others, the curriculum itself, the availability of teaching resources, and the input of all stakeholders other than teachers. These factors were probed in this study by asking related questions in the survey and the interviews. Statements related to the national examination, the time required for planning and teaching inquiry lessons, the class size, the teachers' preparation at university and the students' lack of enjoyment for doing inquiry are considered to be external factors. The teachers' personal enjoyment of their job, personal experience in inquiry, confidence to apply the inquiry approach and feeling towards adopting change were seen as internal factors.

Assertion 4:

Teachers' inquiry practices are positively influenced by some factors such as meeting examination demands and enjoyment of teaching through inquiry, and negatively influenced by others such as lack of teaching time, resources for practical work and confidence associated with inadequate training

Teachers' practices with regard to the implementation of a curriculum change are influenced by a variety of factors, often acting in opposite directions. One of the areas of interest of this study was to find out factors influencing teachers' practices in connection with the implementation of IBST. Assertion four was constructed and is presented along with data from the questionnaire and interviews and inferences drawn from these. Teachers were asked the extent to which they agree or disagree with 10 statements about factors that influence their practices with regard to implementation of IBST. Responses were reported on a 5-point scale where 1 = Strongly agree (SA); 2 = Agree (A); 3 = No opinion (NO); 4 = Disagree (D); and 5 = Strongly disagree (SD), and are summarized in Table 6.5 and discussed under the relevant sub-assertions.

Table 6. 5. Respondents' responses about factors influencing their current practices (%)

Proposed statements	SA	A	NO	D	SD	Mean	SD
1. Using inquiry prepares learners for national examination	41	41	13	3	1	1,82	0.86
2. Planning and teaching inquiry lessons is more time-consuming	39	41	4	11	4	1,98	1.12
3. I enjoy my job more than before now that I am using inquiry	33	39	19	8	2	2,08	1.01
4. Classes are too big to do inquiry	34	34	9	14	8	2,27	1.29
5. The way I was taught at university/ college prepared me to use this approach	11	21	18	22	23	3,25	1.36
6. Don't have enough experience to do inquiry teaching	4	20	12	37	25	3,57	1.22
7. I feel confident in applying inquiry teaching approach	9	15	16	29	31	3,56	1.32
8. I don't feel the need to change the way I have been teaching over the years	6	8	14	36	36	3,88	1.16
9. Students do not enjoy inquiry	2	9	16	42	31	3,91	0.10
10. Inquiry doesn't help students to pass their exams	3	5	15	37	40	4,05	1.02

Further data, including the reasons that motivate teachers' actions or that prevent them from adopting and implementing an inquiry approach, were sought by means of interviews. These involved a number of probing questions on the main goal that may influence one's teaching, the reasons behind their frequency of using inquiry in their daily teaching, and the major reasons that prevent them from using inquiry. The following sub-assertions were based on the data sources.

Sub-assertion 4a: Most common factors that positively influence teachers' practices in implementing an inquiry teaching approach are the belief that it prepares learners for examinations and that they find it an enjoyable instructional method

It is indisputable that teachers are key to success in implementing any curriculum change. However, among the problems that teachers associate with the use of inquiry, some may be real while others would be perceived and sometimes may be used as an excuse for not implementing inquiry. With regard to this sub-assertion, a close look at the data as summarized in Table 6.5 revealed two trends, one of strong agreement (items 1, 2 & 3) and another of strong disagreement (items 8, 9 & 10), with mixed feelings toward the three in the middle (items 4, 5 & 6). There was strong agreement that using inquiry prepares learners for the national examination; on a scale from 1 to 5, a mean of 1.82 and a standard deviation of 0.999 indicates that the national examination is a determining factor influencing teachers' practices. Further, it can be seen that if we use cumulative counts, over 80% agree with this statement. Similarly, a mean of 2.08 and a standard deviation of 1.008 indicate that using inquiry has made their job more enjoyable, with almost three-quarters (72%) agreeing with the statement.

This positive view of introducing inquiry is also supported by the teachers' agreement that they felt the need to change the way they had been teaching over the years (item 8 in Table 6.5), and the cumulative count gave 72% who felt this. Similarly, data from the last item (item 10), where slightly more than three-quarters (77%) disagreed with the statement that inquiry doesn't help students to pass their exams, supports the concern with exams based on data from the first item. Data from the first three items can be interpreted that although teachers strongly agreed that planning and teaching inquiry-based lessons are more time-consuming (80% agreed, $M = 1.98$, $SD = 1.17$), teachers' enjoyment of their job as a result of using inquiry and the fact that inquiry prepares learners for the national examination were found to positively influence teachers' practices with regard to the use of inquiry.

This trend was supported by data from the last three items, as mentioned earlier. It can be seen that only very few teachers (14%) do not feel the need to change the way they have been teaching over the years, while most (72%) feel the need to do so. Thus, the willingness to adopt change, expressed as feeling the need to change teachers' practices, appeared to be a factor positively influencing teachers' practices with regard to inquiry. On item 9, the high

mean 3.91 and small standard deviation 0.10 indicate strong disagreement that students do not enjoy inquiry. Finally, items 1 and 10 together indicate that the exam is a positive factor. The strong agreement (82%) that using inquiry prepares learners for the national examination is supported by the corresponding disagreement that inquiry doesn't help students to pass their exams (77%).

Interviews provided more data in supporting this sub-assertion that the examination had a positive influence. In addition to the factors identified from the survey as positively influencing their practices, the teachers interviewed also mentioned a number of other associated factors. In many instances the pass rate in the national examination was seen as a consequence of achievement of other goals and as positively influencing teacher practices. For example, of the 15 teachers who were interviewed, 10 indicated that they have a variety of teaching goals, but all these contribute towards the goal of passing and getting good marks in exams. The following two quotes are illustrative:

At O level learners try to understand concepts and apply them to their daily life and to their environment. But also we do train our learners with the aim of enabling them to pass their national examination at the end of O level. So in brief, the major goals are to understand the nature and to protect the environment on the basis of what they have learnt in class and also to be prepared for the national exams that they will write at the end of S3. (Interview MP/EFOTEK)

My main goal when I teach science is about the understanding of concepts and of course to get good marks on tests, especially at the end of S3. That is where teachers are judged whether they teach well or not. [...] So by whatever means and teaching method I use, I have to make sure that I cover the whole prescribed curriculum and get a good pass rate of my learners at national exam. (Interview RS/ESC)

Another teacher shared the same point of view, acknowledging the preoccupation with passing the national examination at the end of S3:

As I said, the main goal is to teach for application purpose not only for knowing facts and concepts but being able to apply knowledge in any situation that was not necessarily discussed in class but that can be encountered in life. So among these purposes of teaching science, the understanding of the nature of science and its process come first. But good marks on tests and exams, especially at the end of S3, are also a big preoccupation because schools and teachers are judged on the basis of their rank at national examination. (Interview MMJ/ESS)

In this perspective they mainly emphasized application to everyday life and awareness and protection of the environment among other goals when teaching science, but all with the major concern of passing and getting good marks at national examination, as illustrated in the following two quotes from teachers:

My main goal actually considers almost all those aspects of teaching science. I want my learners to understand physics concepts and be able to interpret or explain phenomena they can encounter in their daily experience, at home, on their way to or from school, in brief in their environment. As I have said, learners do some investigations in groups and they present in front of the whole class and they become able to answer questions from colleagues. So another goal is to familiarize my learners with talking and discussing science issues, to overcome the fear of science. All this of course aims at enabling them to pass with good marks at national examination. (Interview NT/ ASPEJ)

I think that all those aspects are considered in my teaching. For example, my main goal is about teaching the process of science, but I do this in order to fix some science concepts and of course I want my students to pass exams and tests. (Interview IMC/DBK)

The above data enabled the assumption that the examination concern was a determining factor that positively influences teachers' practices with regard to inquiry. The variety of goals that they set for their teaching had in common the examination pass, a criterion against which the teaching and learning achievement seems to be assessed.

The second factor that had a positive influence on teachers' use of inquiry was the increased enjoyment of their job. They explained this increased enjoyment by referring to the approach as a good method for promoting learners' understanding and involvement in science:

I am personally convinced that it is the best way of teaching science but would work better if mixed with other approaches. I say that because it was proved that the traditional way of teaching used to be limited at the lower level of Bloom's taxonomy and consisted at promoting just memorization. But through inquiry, learners develop a kind of personality and learn how to think and to try alternatives when attempting to solve a problem. Also, when learners learn by doing they can find ways of applying what they have learnt in other situations. You can see that even during their free time they continue discussing issues they were involved with in classroom activities for they had their hands-on and were given opportunity to discuss. However, the approach is not always used in our schools due to a number of reasons, including the

lack of confidence of teachers to implement it, the lack of materials and the generally poor conditions in many schools. But once one tries to use inquiry, it is a very enjoyable teaching approach. (Interview MC/TTC)

In most other cases these benefits motivating their preference and enjoyment were also associated with exam results, as illustrated below:

My opinion is that it is the best way of teaching science despite problems related to its implementation. It enables learners to actively take part in their learning process and therefore can at the same time earn good marks on tests and exams. It improves learners' thinking skills and the science that they learn through inquiry serves them in solving problems they encounter in their daily experience. So, if all schools were able to solve problems related to teaching resources, I would suggest that all science teachers embark on the journey of teaching science through inquiry and the teaching of science would be more enjoyable and rewarding. (Interview DE/MGS)

My opinion is that there is no better way of teaching science apart from this one. I believe that even my learners' achievement on tests and exams has significantly improved due to the use of learner-centred methods. (Interview KD/SAR)

This satisfaction has been acknowledged through the positive attitude of teachers towards the introduction of (see Chapter Five) and their preference for inquiry-based teaching over the traditional approach, even when the two would lead to similar results on tests and exams.

From the above analysis the general perception is that the examination concern and teachers' enjoyment of their job resulting in integrating inquiry in their teaching had a positive influence on their practices with regard to implementation of IBST. These factors are partially supplemented by the pre-service training and the teachers' personal research.

Sub-assertion 4b: Teachers reported a number of factors negatively influencing their practices with regard to implementing IBST. The most frequently indicated are teaching time, resources for practical work and confidence associated with inadequate training

Similar to the previous section, data supporting this sub-assertion were obtained from the survey and the interviews. In the first instance, analysis of data presented in Table 6.5 also revealed factors which negatively influenced teachers' practices in connection with the use of IBST. The most frequently mentioned were the time, resources and confidence, that

they attributed to the quality of their training (that they felt was inadequate). However, a few mentioned other factors such as lack of experience, class size and the workload that they associated with the time factor. Data from Table 6.5 show that time is an important factor that negatively influences the implementation of inquiry, with 80% of respondents agreeing that inquiry lessons' planning and teaching are more time-consuming. The time factor was mostly associated with the heavy workload. The survey provided only the picture of teachers' workloads, while the interviews revealed that the heavy workload had a negative impact.

Data from the survey revealed that the teachers' workload was extremely heavy to fulfil the teaching requirements, especially with inquiry being new and unfamiliar to them. Of the 128 teachers who provided information related to their workload, only 17% had more or less than 18 hours per week, and combined the teaching load with other administrative duties, such as head or deputy head teacher. Forty per cent have from 20 to 24 hours per week, with 20% having 24 hours per week; the same percentage of 40% has from 25 to 30 hours per week, and 4% have more than 30 hours per week, with one extreme case reaching 36 hours per week. Reduction of the workload was also highlighted through interviews as a strategy teachers felt should be adopted to enable them to better implement the new curriculum. For example, this teacher reported that:

[...] particular attention should be paid to science teachers by reducing the number of hours of teaching per week allowing them to prepare experiments or to try to make some teaching aids. It would be better if a science teacher was given 18 hours of face-to-face teaching and spent the rest of time dealing with practical and material aspects. (Interview NT/ASPEJ)

Furthermore, the class size was seen as problematic. About one-third of schools surveyed have more than 50 learners per class, and 68% of teachers agreed that classes were too big.

As for confidence and experience, data revealed that teachers held mixed feelings. They were to some extent contradictory, as similar percentages reported having experience and at the same time not feeling confident in applying an inquiry teaching approach. In fact the contradiction seems to be pronounced, as the two statements present almost similar distributions: 24% agreed to not having enough experience to do inquiry teaching and felt confident in applying inquiry teaching approach, while respectively 62% and 60% disagreed.

These two items also have very close means and standard deviations ($M = 3.57$, $SD = 1.22$ and $M = 3.56$, $SD = 1.32$ respectively).

Another factor which appears to have influenced teachers' use of inquiry was their pre-service training. Responses to this item were mixed ($SD = 1.38$), with about 45% indicating that they were not prepared and 33% indicating that they were prepared. Even the 18% who neither agreed nor disagreed can also be seen as an indicator of inadequate pre-service training. Further analysis of data from the interviews corroborated the findings from the survey about the negative influence of teachers' preparation. Some teachers pointed a finger at pre-service training as being responsible for their lack of preparation to teach inquiry. The two following comments from teachers illustrate the inadequacy of pre-service and the need to reinforce in-service training. This last aspect is further discussed in the next section as one of the strategies for better implementation of inquiry:

For science teachers' preparation, some institutions of teacher training or universities do not prepare science teachers well. [...]. So I think the first thing is teachers to be trained to understand and to know how to apply this method before starting teaching. But the same kind of training can be organized even for those who are already working as science teachers. (Interview KS/KSS)

I think there is no contradiction because even what we are using now to deal with this new method is what we have gained from the higher learning institutions, but it was not enough. It was not enough because we need more improvement. The higher learning institutions should take this matter very seriously and bring it in the Rwandan context, and even during the teaching practice the supervisors, I mean the lecturers, must emphasize this new method. Actually most of the supervisors who visited us during that school practice period did not emphasize this teaching method, leaving student teachers thinking that what they have been told was enough. So there is a need for improvement since what we have gained from higher learning institutions was not enough. (Interview NP/MSS)

Table 6. 6. Teachers' responses on the role of some aspects in their preparation (%) (*)

Ways of preparation	1st	2nd	3rd	4th	5th	Ranking
Pre-service training	63	11	9	7	9	1
Own daily experience	21	31	31	9	7	2
In-service programmes	13	21	21	19	24	3
Discussions with colleagues	3	24	24	35	12	4
Head/deputy head of school	3	12	13	23	40	5

(*) rounding error of $\pm 1\%$

The pre-service training was also seen by some from two perspectives, with both positive and negative influences. These same mixed feelings were also perceived from the interviews, through responses to the question on teachers' views about their preparation. They saw it as having played a most important role in science teachers' preparation. In response to the Q 3.2 about ranking (from 1st = 'Most important' to 6th = 'Least important') of some suggested ways of preparing them for teaching science through inquiry, pre-service training was ranked first, as indicated in the Table 6.6. In the question it was further suggested that respondents indicate any other aspect they felt had played a role, but very few did so, and therefore the related information was disregarded as were those ranking 6th making the total less than 100% for most statements.

Further details were reported through interviews about the role played by the pre-service training, from which any improvement can be built upon therefore being seen as having a positive influence, while others saw it as not enough. The following two comments by teachers reflect these two opposite views:

For me I consider the pre-service training as the most important and that it played a very significant role in my preparation for this profession. We were exposed to different experience first with the science subject matter and the subject teaching method modules, then during teaching practice. It was really a good preparation. However, once in the profession you find yourself exposed to new realities that require in-service trainings. So there is no need to change the way higher training institutions of science teacher training work, rather there is a need of putting in place strong in-service training programmes and making sure they work. (Interview MMJ/ESS)

For me I studied at KIE. We had science subjects and subject teaching methods and we went through teaching practice exercises but we didn't really focus on inquiry. Though we were told about the active pedagogy centred on learners' activities, we were not explicitly trained in using an inquiry teaching approach. Even the tutors during teaching practice used to look at how we were teaching regardless of any particular method. So as the new science curriculum puts more emphasis on inquiry, I think that teacher training institutions should change and adapt the subject teaching modules to the new science curriculum requirements. Otherwise, new teachers once in schools would need more training. (Interview IMC/DBK)

What appears to be in common is that they all have the need for in-service training, and thus not all teachers felt that their pre-service training prevented them from doing inquiry. The majority of evidence points to a problem with pre-service training, but some positive points were made by some teachers.

In-service training was also explored, and data revealed three components from which it can be established that it had a negative impact on teachers' practices, mostly due to its inadequacy. Firstly, the in-service training organized had a low coverage, since only 71.1% had attended at least one in-service training session. Secondly, it was ranked 3rd (Table 6.6) for the role it played in teachers' preparation for using inquiry. Finally, both the focus of it and the areas teachers most benefited from during in-service training were not explicitly inquiry-oriented (Tables 6.7 and 6.8).

It can be seen that in-service training had an uneven distribution. By doing some grouping or cumulative counts and considering the first two rankings to mean an important role with a less important role for the two last rankings, it can be seen that in-service training was seen to have played a significant role by only 34%, against 43% who saw it as less important. As for the focus during in-service training, responses to Q 3.6 as summarized in Table 6.9 indicate that they mainly focused on general science teaching methods and the use of the new science curriculum, but no particular emphasis was explicitly put on the use of an IBST approach, and can therefore be seen as having little influence on teachers' practices towards the use of inquiry.

Table 6. 7. Teachers' reports about the main focus during in-service training attended

Areas focused on during in-service training	Frequency	%
Science teaching methods	32	21
Use of the new science curriculum	32	21
English as medium of instruction	2	1
Participative teaching methods	2	1
Learner-centred education	5	3
Use of teaching aids/resources	4	3
Computer and Internet skills	1	1
Other	29	19
No answer	43	30
Total	150	100

This indicates that there was little if any explicit focus on inquiry. There is no specific indication whether the 21% who reported having focused on science teaching methods were specifically making reference to inquiry or teaching methods in general.

The relatively high number of those under the category 'other' may be due to the fact that the previous question about whether they had attended any in-service training since they had started implementing the new curriculum was not clear about what specific training session was being referred to. Therefore, in reporting on what was the focus of the one they had attended, some mentioned one organized by the Japanese International Cooperation Agency (JICA) through funding the Strengthening Mathematics and Science in Secondary School project (SMAS), which focuses on mathematics and science teaching at secondary school in general.

As a reminder, it was earlier highlighted that the existing teachers' professional development programmes are still occasional and not yet centrally coordinated, leading to some teachers finding themselves attending several small-scale training sessions which do not necessarily respond to the real needs of the moment. As for the one-third (30%) who did not answer the question, these could be teachers who had not attended any INSET. The low coverage mentioned earlier can be the reason, because in response to Q 3.5, only 71.1%

reported that they had attended at least one in-service training session since starting implementing the newly revised science curriculum.

The areas teachers most benefited from during the training they attended also do not indicate a particular benefit for implementing inquiry, as shown in Table 6.8 summarizing responses to Q 3.6.

Table 6. 8. Responses on areas teachers most benefitted from during training attended

Areas benefitted	Frequency	%(*)
Science subject matter	32	21
Practical-based lesson planning	14	9
New science teaching methods	8	5
Carrying out experiments in lab	4	3
Improvisation of teaching aids	3	2
Combination of many of the above areas	42	28
No answer	47	31
Total	150	100

(*) rounding error of $\pm 1\%$

It can be seen that the training was actually beneficial mainly in a combination of many of the areas, but there is no indication of inquiry. It can also be assumed that the high rate of non-responses (31%) could be due to the low coverage of the training mentioned or simply to the feeling of not having gained anything from the training. All this analysis of data related to training showed that it was not sufficient or fully focused enough so as to influence positively teachers' practices with regard to implementing IBST approach.

Lack of resources was also reported as a factor negatively influencing teachers' practices with regard to the use of inquiry. This was discussed in the light of data from interviews only. They mostly pointed out the schools' conditions, mainly associated with the lack or a shortage of resources. Responses from interviews indicated that at schools where conditions were conducive or very good, implementation of the new science curriculum was much easier, and that it was harder or sometimes impossible where schools were too poor to afford the minimum of teaching resources. The following quotes show two extreme situations experienced by teachers referring to the equipment and resources in their schools. In the first case the situation is described as very conducive:

This school is a little bit advanced. So I go quickly because all materials are there, our library is there, our lab is there, even the Internet room is there. So we implement it easily, it is easy for me because I help them to go there, I give them the topic and they go there to check, and after they give the results. (Interview MA/BSoS)

At the other extreme, the following situation was described as not conducive, where not much would be expected:

The conditions in this school are not conducive at all for teaching science. You see this curriculum is more activity-oriented and we can just perform very few of them in Biology and none in Chemistry. So what I can say, we just teach in the limits of our possibilities but we can't really claim that we do things the way they should be done. (Interview HJD/GSM2)

Given the primary focus of the study, during the interviews the use of inquiry or the lack of use was probed in depth. For the purposes of analysis teachers' responses to the question of why they did not use more inquiry were put into groups, according to what they were related to. These groups were: (a) personal-related reasons, as reported by five teachers; (b) curriculum requirements-related reasons, such as its width, the fear of not covering the whole syllabus, the relevant teaching methods and concern about the national examination, as reported nine times; and (c) school conditions-related reasons, including resources, teachers' heavy workloads and big class size. In most cases teachers listed a number of these factors which were sometimes associated, indicating mixed feelings over a single factor. The following transcript extract illustrates this:

Apart from what I have said that it requires more time and that we have big classes with a shortage of materials, to be honest I can't claim that I am fully confident in using this approach. Sometimes you can try it and find yourself more leading the lesson than leaving the place to the learners. Maybe I would need more training. But I also think that the curriculum is too large and if you keep focusing on inquiry you might not complete all proposed sections and units, and this seems to be more crucial for S3 students who write the national examination. I think that the conditions under which many schools operate are not conducive for applying teaching and learning though inquiry, it requires specific conditions and environment, but mostly resources and trained teachers. (Interview MMJ/ESS)

In the following example the teacher also associated multiple factors such as time, space, the concern of covering the whole curriculum and even people's resistance to change:

As I said, it requires more time and more space to plan for an inquiry-based lesson and we have so many hours per week; 27 hours is too much. Also especially with S3 students, we run to cover all units from the curriculum to avoid being blamed if they are asked on topics that we have skipped over. On top of this, honestly, I think that people don't enjoy changing the way they have always done things, because I do find myself not changing with any real motive. (Interview HA/ENA)

In another example a teacher associated the time required for inquiry-based lesson planning with the workload, lack of resources and personal feeling of accountability related to the national examination results:

I have already said that the time, I mean the workload is heavy and preparing such lessons requires more time than just preparing a traditional lesson based only on reading books and preparing the lesson. Also the lack of certain materials is another major reason. Our labs are poor and when it comes to S3 learners, we have at all costs to cover the whole curriculum, for we don't know chapters which the national examination will focus on. When you see that you run the risk of not finishing all the assigned units in the curriculum, you shift back to the traditional direct teaching even though you know that inquiry would be the best way for sustainable knowledge acquisition. (Interview IMC/DBK)

Similarly, the teachers' workload and preoccupation with the national examination, associated with many other factors such as teaching materials and the length of the syllabus, were pointed out several times as preventing teachers from using inquiry. For example, this teacher reported as follows:

Ok, for me I think, I feel like the syllabus is too long and because of the national exam for the S3, I am in a hurry saying that eeh my students will say and the administration will say that the teacher didn't finish the syllabus. And for that fear, sometimes I can refrain from using it so that I can finish. And also as I mentioned before I have some problems of getting materials. If I don't have materials and products sometimes I won't be able to use inquiry and keep teaching traditionally, but I also eeh, I can think of the number of hours that we have. Imagine someone who is teaching like 6 or 7 hours per day. He or she cannot manage to plan like for procedures of a practical and then at that time he or she will not use that method. So in summary, there is time, the length of syllabus and the workload, I mean number of hours. (Interview DE/MGS)

The teachers' confidence in using inquiry correctly was one of the issues associated with personal reasons for not implementing the inquiry teaching approach:

As I told you, I am aware of some of the advantages of teaching science through inquiry even though I don't use it. I would definitely like to use it but I am not confident enough. Even when making use of some activities that I may consider inquiry-related, I am not very sure if they are used at the right place and in the right way to benefit learners. (Interview RS/ESC)

Another aspect of resources to support inquiry could be human resources. When asked who they obtained help and support from, the majority of teachers indicated themselves. This indicates that the support system in the schools is not well developed, because they reported that they mainly relied on their own initiative and colleagues rather than being helped by the principal or deputy principal. This was in response to the question where teachers were asked to rank (from 1st = Most helpful to 6th = Least helpful) the source of help they may receive when they make use of inquiry in their teaching (Q 3.3), as reported in Table 6.9.

Table 6. 9. Report on help teachers receive when making use of inquiry (%) (*)

Help from	1 st	2 nd	3 rd	4 th	5 th	6 th	Ranking
Head of school	10	11	26	46	5	3	4
Deputy head of school	8	18	46	22	6	1	3
Colleagues	12	57	19	11	2	0	2
Own research	73	17	8	2	1	0	1

(*) rounding error of $\pm 1\%$

Data from responses to the last category 'Other sources of help' were provided by a handful of respondents (respectively 69% and 82% did not consider any other source) were disregarded as they seemed of little value in terms of appreciating the type of support they get.

The above has provided evidence supporting the assertion and sub-assertions associated with factors influencing teachers' practices with regard to the implementation of IBST (assertion 4). The analysis identified factors that positively influenced teachers' practices. Teachers' enjoyment of the use of inquiry and concern about the national examination were the most important factors to positively influence teachers' practices in connection with IBST and learning. On the other hand, the time required for using inquiry in association with the heavy workload of teachers, the training and lack of resources negatively influenced teachers' use of the inquiry-oriented curriculum. All these together show that in

terms of implementing inquiry teachers see it differently and are influenced in different ways by a variety of factors, either internal or external, with both positive and negative influences. In the commentary section this is discussed and linked to the literature and the study's framework as factors associated with the implementation of curriculum change, with particular reference to the change relating to the introduction of IBST.

6.3. STRATEGIES FOR MORE EFFECTIVE IMPLEMENTATION

One of the areas of interest of this study that was captured in the last research question was how participant teachers think IBST could be better implemented. As critical agents for bringing change into the classroom, teachers should be the major source of evidence about the introduction and implementation of curriculum change. They were therefore surveyed and interviewed as a way of collecting information related to the associated research question.

In the survey teachers were given a list of seven statements and asked to display their level of agreement on a five-point scale where 1 = Strongly agree (SA), 2 = Agree (A), 3 = No opinion (NO), 4 = Disagree (D) and 5 = Strongly disagree (SD). One question from Section 3 of the questionnaire (Q 3.8) also provided information as to what the focus for further in-service training should be as a strategy for better implementation of inquiry. In the interviews participants were asked a number of questions, including about strategies they thought can be adopted in order to have well-trained teachers who are able to implement the new science curriculum, and the type of support they would like to be provided for better implementation of an IBST approach. Analysis of information obtained from these two sources generated the following assertion and sub-assertions.

Assertion 5:

Teachers agreed that a number of interventions would make implementation of inquiry in the classroom more effective. They did not isolate one particular intervention but referred to a combination of many, those most frequently mentioned being resource provision and professional development

In the survey teachers were asked the extent to which they agreed or disagreed with a number of statements (Q 6.1) describing some suggested concrete interventions. Responses are reported in Table 6.10.

Table 6. 10. Respondents’ responses on ways to make inquiry teaching more effective (%)

Proposed statements	SA	A	NO	D	SD	M	SD	Ra
1. Schools to be supplied with required science teaching resources	82	17	0	0	1	1.22	0.58	1
2. Teacher training institutions to change the way they prepare science teachers	58	33	6	3	0	1.53	0.73	2
3. Science teachers with few skills compelled to attend courses in holidays	55	37	5	3	1	1.57	0.77	3
4. Science teachers’ workload to be reduced to allow them to prepare practicals	55	34	5	3	3	1.64	0.92	4
5. Teachers using inquiry approach to be given extra bonus	53	22	17	5	3	1.83	1.06	5
6. Science teachers’ skills to do inquiry should be evaluated	32	50	11	4	3	1.96	0.91	6
7. Under-resourced schools not required to follow an inquiry-based curriculum	16	14	16	29	25	3.33	1.40	7

Ra= ranking.

From this table it can be seen that provision of resources to schools was ranked first in term of agreement, even though there was relatively strong agreement with almost all the suggested statements. This may give rise to further interrogation, because it seems that even those who previously reported having laboratories still reported the need of resources. The low mean indicates strong agreement with the statement and the low value of the standard deviation indicates that most teachers responded in the same way ($M = 1.22$, $SD = 0.58$). In fact, 99% of teachers agreed that more resources would make a difference. What further emerged from data in this table was the agreement with almost all of the statements. The aggregation of data for “agree” and “strongly agree” together as indicating agreement indicated that at least 75% of teachers agreed with the six first statements. This was also

evidenced by low means and standard deviations where, on a scale from 1 to 5, the means were less than 2 and the standard deviations less than or equal to 1. Only the degree of agreement with the last statement (under-resourced schools not required to follow an inquiry-based curriculum) had a wide distribution ($M = 3.3$, $SD = 1.4$). However, when more analysis was undertaken on this last response distribution, no significant differences were found across the categories of qualification, number of years of teaching experience and school location. Resources provision was further reiterated through individual comments on the last question of the questionnaire; this had been highlighted earlier as preventing teachers from using inquiry in their daily teaching.

The interviews provided more information about interventions that teachers felt would make a difference. Respondents reported a number of strategies they thought should be put in place, and the type of support they would like to be provided with for more effective IBST implementation. Analysis of the 15 interview responses relating to strategies and support for better implementation of IBST led to grouping them into three categories: (a) readjustment of pre-service teacher training; (b) provision of in-service training; (c) and institutional support including reviewing science teachers' workloads, financial support, reducing class size, resourcing schools, and promoting partnership among educational boards and institutions.

In general, the strategies suggested by teachers referred to a number of factors previously identified as impacting negatively on their practices in connection with implementing inquiry-based teaching. They suggested a variety of strategies, but most commonly referred to were resources provision and teacher professional development, which constitute the basis of the following two sub-assertions.

Sub-assertion 5a: In order to make inquiry teaching more effective, teachers agreed that a number of initiatives could be implemented. In particular they reported improvement of resources provision as the most relevant intervention

Data from Table 6.10 indicate that teachers had a strong belief that provision of resources may guarantee the effectiveness of IBST implementation. From the abovementioned aggregation of data, 99% agreed that schools should be supplied with

required science teaching resources. This belief that resources are essential for making inquiry teaching more effective led some teachers even to think that in absence of resources schools may simply opt out of following an inquiry-oriented curriculum (item 7). About one-third (30%) agreed that if a school does not have resources, it would not be required to follow the inquiry-oriented curriculum.

Resources provision to schools was also mentioned by interviewed teachers; it was reported by five of the 15 teachers in response to the question about strategies that should be adopted for effective implementation of the new curriculum. As for the support teachers would like provided for better implementation of an IBST approach, teaching resources were mentioned eight times. Together these indicated that resources were a top priority. For example, this teacher claimed that he lacks support but put emphasis on the teaching resources:

Yes I lack a lot of support. First of all working in a poor school is a danger both for the teacher and the children. I would like to see, not only this school, but all schools equipped with the minimum required teaching resources for teaching science at O level, because if learners are not well prepared at this level, they won't be good in science even at advanced levels. [...] (Interview NT/ASPEJ)

In another example a teacher also pointed out the lack of resources, but in a more desperate way without any hope of seeing any improvement in the near future. The following is an excerpt from his response as to the kind of support he would like to be provided with:

I don't know if I can call it support. The support applies to someone who has at least something and who needs to be helped in order to improve. For me it is not about support because I lack almost everything considering the state of this school. [...] I lack all kind of resources. It will take time for this school and others that are in similar conditions to reach the level where one can claim satisfactory in terms of teaching science effectively. (Interview HJD/GSM)

As mentioned earlier, resources provision was highlighted several times, but in many instances was associated with other aspects. Despite the almost equal importance they gave to training, some considered this to be of little or no value if not accompanied by the required provision of resources, as can be noted from the following two short quotes:

Actually the training, I mean in-service training as I have just said would be the best strategy. But the training by itself would be nothing if schools are not equipped with all the required teaching materials, relevant textbooks and the whole infrastructure.
(Interview IMC/DBK)

[...] But besides the training of teachers, schools should be equipped with the minimum resources of teaching science; otherwise any other effort would be in vain.
(Interview MMJ/ESS)

From the above it can be seen that resourcing schools is a major concern of teachers, and therefore believed to be one of the main strategies that need to be put in place in order to improve IBST implementation.

Despite seeing lack of resources as preventing them from doing inquiry, some teachers made attempts to overcome this by improvising or resorting to direct teaching, as indicated in Table 6.11, which indicates how they dealt with lessons that required laboratory-based practical work in the context of lack of laboratories and shortage of materials (Q 1.3.d).

Table 6. 11. Ways of teaching in the context of lack of laboratories

Teaching practices	Frequency (N=150)	%
Improvisation	31	21
Lecturing with sometimes drawing	22	13
Visiting neighbouring schools' labs	3	2
Simply ignore practical	11	7
Other practices	21	14
No answer	65	43

The response rate to this question was relatively low (43% did not answer). This high rate of non response is not informative. It is partially due to the formulation of the question, because teachers from schools that had laboratories might have not answered. Improvisation and lecturing were the most common practices indicated. About 7% of those who answered this question reported simply ignoring practicals, but did not specify what the alternative was. Very few (2%) reported collaboration between schools, where a well-resourced school with a laboratory and apparatus could help their under-sourced neighbours. Responses which did not fit into any of the first four codes were grouped under "Other practices". A number of illustrative quotes were provided showing some practices teachers resorted to when facing the

challenge of lack of laboratories and shortage of materials as further probed through interviews. The schools' surroundings were pointed out most often as the source of teaching aids, used as a result of individual initiative, as illustrated in the three following teachers' responses:

We teach with some materials that we bring in class so that learners can observe and discover what to learn. Sometimes we take them in the nature around the school.
(Teacher 22)

Since my subject is a natural science I try to be creative by using elements that the nature provides to us. (Teacher 67)

In biology it is satisfied with the material we can find in our environment. However, for chemistry is a bit difficult, we explain the chemical reaction with drawings or we try to build some models of molecules. (Teacher 86)

Thus the teachers' personal initiative played a very important role in dealing with the shortage of teaching materials. In fact, data revealed that teachers working in similar conditions reacted quite differently with regard to how they dealt with the shortage of resources. Some reported simply teaching only theory, while others would try to borrow from other schools or download some simulated experiments and use computer to show learners.

When more details were probed through interviews, similar trends were reported. Some teachers interviewed indicated that there was encouraging cooperation between schools, where those which did not have required equipment and laboratories could rely on neighbouring schools. This was reported by a science teacher from a public rural school as follows:

We don't have lot of materials in our lab but we can borrow in one neighbouring school which is well equipped and doesn't mind to assist us. Teachers in these two schools help each other and Headmasters maintain such a good relationship.
(Interview HA/EAN)

There was enough evidence that the provision of resources was a major concern of teachers; it is therefore believed to be one of the main strategies to be put in place for more effective implementation of IBST.

Sub-assertion 5b: Teachers indicated that professional development was an important factor for more effective implementation of inquiry in schools; they felt that neither pre-service nor in-service training was adequate.

This sub-assertion was also developed based on data from both the survey and the interviews. Data from Table 6.10 provides evidence in support of this sub-assertion, particularly by analysing responses to items 2, 3 and 6 after aggregating the data. The 91% who agreed that teacher training institutions should review the way they prepare science teachers is an indicator that the initial training of science teachers is questionable. The low mean and standard deviation also are informative in terms of questioning the pre-service training ($M = 1.53$, $SD = 0.73$). It was further found that the view that the teacher training institutions should change the way they prepare science teachers was statistically different across categories of qualification ($U = 1002$, $p = .021$), where unqualified teachers (A2) most often reported that the way teachers were trained should change. Here one may ask how they know what needs to be changed, since they have not been trained in these institutions; we therefore assume that they wanted to emphasize that teacher training institutions need to focus on inquiry teaching because they acknowledge that it is what they most need.

From the same table it can be seen that 92% of teachers were in favour that science teachers with few skills in inquiry should attend courses mostly during schools holidays, and both the low mean and standard deviation ($M=1.57$, $SD = 0.77$) are tell-tale signs that initial teacher training should be reviewed to meet the demands of teaching science through inquiry. In the same perspective, 82% agreed that science teachers' skills to perform inquiry be evaluated. This discussion supports that it is essential that professional development be improved through training and evaluation. In the same survey responses to Q 3.8 also illustrated that teachers saw training as a way of improving their skills for implementing IBST. They expressed their views through a number of areas they wished they could focus on if given an opportunity to attend any in-service training programme, as summarized in Table 6.12.

Table 6. 12. Responses on areas to focus on in next possible training

Areas to focus on in next training	Frequency	%
Science subject matter	43	29
Practical work in lab	20	13
Making teaching aids	3	2
Experiments from the new curriculum	2	1
Use of audiovisual in science teaching	2	1
Combination of the above with many other areas	70	47
No answer	10	7
Total	150	100

From this table (Table 6. 12), the 48% who would like to focus on more than one area was an indication that there was a need for more in-service training as a way of improving their science teaching. They mentioned a variety of areas they would like to focus on if given the chance to attend training. Practical-based lesson planning, active teaching methods, assessment, inquiry-based lesson planning and improvisation of teaching aids were frequently indicated, sometimes with further details. For example:

Improvisation, planning hands-on and practical lesson in which students are able to learn the importance of the subject through experiment. In-depth understanding of illustrating concepts in a limited environment. Enhancing my level of tackling the challenges that accompany IBST. (Teacher 111)

Planning inquiry-based lesson and investigation, experiments and manipulation of materials, making science teaching materials. (Teacher 149)

The use of teaching materials related to this new curriculum, experiment in lab, active teaching methods and assessment approaches. (Teacher 139)

The 29% and 13% respectively who wanted training in science subject matter and practical work in a laboratory show that the initial training received by teachers by itself is not sufficient, and therefore should be revisited or supplemented by adequate professional development programmes given the introduction of a new curriculum.

Data from interviews also provided evidence to support the inadequacy of the initial teacher training and the need to improve professional development. In order to have well-trained teachers able to implement the new inquiry-based science curriculum, the strategy

most commonly reported as necessary by almost all interviewees was in-service training. In many instances this was associated with putting in place a strong professional development programme. It was reported 17 times, which means it was sometimes highlighted more than once by the same participant. Pre-service training, which was in second position, was mentioned four times, and seemingly was perceived as challenging the way higher teacher training institutions prepare their student teachers:

The first thing is that university level or other science teachers' training institutions, they have to apply this method. Lecturers or professors at that level should be aware of that method and so they can apply it to their student teachers, and therefore when the student teachers leave the university they know already the method and how to apply it. That could be a good thing. (Interview KS/KSS)

Another teacher went on to say that whatever good came of pre-service training would be of little value if not supplemented by more sustainable in-service training:

I think it is about looking at both the pre-service and in-service training. Beside the quality of new graduates, in-service training programmes should be put in place and reinforced if we expect to improve the quality of teaching and learning of not only science but in any other field. They would be good enough at the end of their studies but once in the workplace they find different realities. So continuous and sustained in-service training is one of the ways of having good teachers and therefore implementing the new curriculum. [....] I think that it can be organized through workshops, seminars during holidays. It is up to the MINEDUC and the concerned staff to choose the more relevant programmes, but in any case the new teaching methods proposed in the curriculum should be the main focus as well as the use of new apparatus as science is moving with new technologies. (Interview RS/ESC)

There was not always agreement as to whether the problem was pre-service training and whether teacher training institutions should change the way they prepare science teachers. Two tendencies were displayed, one advocating the status quo, the other advocating a change in the way higher teacher training institutions prepare science teachers. However, they both shared the idea of reinforcing in-service training programmes. The following two excerpts from interviews illustrate the two tendencies and the shared idea:

For me I consider that the pre-service training is the most important and that it played a very significant role in my preparation to this profession. We were exposed to different experience, first with the science subject matter and the subject teaching methods modules, then during teaching practice. It was really a good preparation. However, once in the profession you find yourself exposed to new realities that require in-service trainings. So there is no need to change the way higher training institutions of science teachers training work, rather there is a need of putting in place strong in-service training programmes and make sure they work. (Interview MMJ/ESS)

I think there is no contradiction, because even what we are using now to deal with this new method is what we have gained from the higher learning institutions, but it was not enough. It was not enough because we need more improvement. The higher learning institutions should take this matter very seriously and bring it in the Rwandan context, and even during the teaching practice, the supervisors, I mean the lecturers, must emphasize this new method. Actually most of supervisors who visited us during that school practice period did not emphasize this teaching method, leaving student teachers thinking that what they have been told was all enough. So there is a need for improvement since what we have gained from higher learning institutions was not enough. (Interview NP/MSS)

As for the kind of support teachers most lack or would like to be provided with for more effective implementation of the IBST approach, training was mentioned by 13 of the 14 teachers who were asked the question. This indicates that professional development of science teachers deserves particular attention in the view of practicing teachers, in order to expect satisfactory results in implementing the new science curriculum. For example, one teacher claimed that “In my view, I think that there is no shortcut besides keeping science teachers updated through regular in-service training” (Interview HJD/GSM). All of this serves as evidence in support of the sub-assertion about the critical role of professional development in improving the use of inquiry in the science classroom.

Beside these two major strategies, namely the supply of resources to schools and implementation of adequate professional development programmes, the interviews revealed other ways teachers think IBST could be made more effective. Participants made many different comments, but most frequently reported were the need for intensifying in-service science teacher training and equipping all schools with the required teaching resources. Teachers also commented on the difficulty of implementing an IBST approach in the Rwandan context, implicitly referring to schools’ poor conditions for teaching science.

There were also comments related to the need for incentives for science teachers, and many teachers wished their workload be reviewed downwards. The previous section highlighted the heavy workload as negatively influencing teachers' practices with regard to the implementation of inquiry teaching, and 89% of respondents to the questionnaire agreed that science teachers' workload should be reduced. Workload reduction was also mentioned in the interviews as one of the strategies teachers think should be adopted for more effective implementation of the new curriculum. It was even perceived as support teachers would like to be given so that they can be expected to achieve teaching through inquiry. Interviews also corroborated these data. The following are examples reported by teachers:

Another thing that may be done is to reduce the number of hours of teaching per week because the current heavy workload doesn't allow us [*teachers*] enough time to prepare our courses. (Interview NN/GSSBS)

Another issue which is almost common to all science teachers is about the workload that cannot really allow one to fulfil the requirements of using inquiry in teaching science. It is time demanding in terms of lesson planning even though you can later relax a bit once learners are fully engaged into activities. If one can have like 15 hours per week, the remaining time can be used for preparing activities, testing experiments, making some apparatus, marking and so on. (Interview HA/EAN)

As I said before, classes are very big and we have too many hours. If these two issues could be addressed, implementing inquiry in my classroom could be much easier and the two sides, learners and teacher could enjoy it. (Interview MD/TTC)

Some teachers made comments requesting that principals also be trained in the use of the new science teaching approach, so that they can provide teachers with the required support. In fact the importance of leadership from principals in improving the quality of teaching and learning in their schools (Fullan, 2001) is, among others, one of the components of support needed for implementing a change, especially in shifting from a traditional didactic style of teaching to inquiry-based teaching (NRC, 2000).

Both the survey and interviews also highlighted financial issues, with a few teachers adding that management support and provision of accommodation close to schools would also enable them to better implement inquiry in their classroom. The survey revealed that 75% agreed that teachers using inquiry should be given an extra bonus. This was reinforced through interviews, where this was expressed not only in terms of an increase in salaries of

teachers in general and for science in particular, but also in terms of funds teachers can use to purchase teaching materials. In most cases the salary increase was associated with a range of other strategies and interventions; for example, this teacher associates the salary increase with the workload and training:

But over all this the salaries of teachers should be revised upwards but particular attention should be paid to science teachers by reducing the number of hours of teaching per week, allowing them to prepare experiments or to try to make some teaching aids. It would be better if a science teacher was given 18 hours per week of face-to-face teaching and spends the rest of the time dealing with practical and material aspects. Also, as I said, we need to be trained in everything new that is brought into the system like ICT, new teaching methods, use of certain apparatus, even to go for further studies or study tours in other countries. (Interview NT/ASPEJ)

In other instances the required budget would be for supporting teaching, as these two teachers stated:

The support I lack is mostly the financial support. Let me give you here an example. For example, when we have to study the blood circulation system or the respiratory system, we should normally be having animals to dissect. But in our schools where there is no farming, there is a lack of financial support for purchasing the required materials. (Interview KD/SAR)

Always we need money to buy those books, materials that are not available in our school. If I get money, I can buy them myself and bring them to show to my students. For example, if I have to teach some optics topics, I can buy my own camera and bring it in my class instead of borrowing from somebody else. (Interview MA/BSoS)

It can be seen that there are a variety of initiatives that teachers identified and which may contribute to making implementation of inquiry-based teaching more effective. Once these strategies are implemented and teachers receive the support they need, more successful curriculum enactment would be achieved.

The next and last section of this chapter is a commentary and discussion of the findings associated with teachers' practices, factors influencing these practices, and strategies for more effective implementation of inquiry.

6.4. COMMENTARY

According to Kerlin, McDonald and Kelly (2009), the science education community still has few empirical examples of widespread inquiry instruction that can serve as models for science teacher education. As a result, when teachers think of teaching science through inquiry they find themselves involved in a wide variety of approaches that may count as inquiry. It would therefore not be surprising that when implementing IBST, teachers have a variety of practices and go through a range of several activities. In this section, evidence supporting the assertion that more traditional classroom activities predominate compared to inquiry-oriented practices was provided. It was found that when teachers participating in this study made an attempt to include inquiry in their teaching, they generally followed a traditional structured investigation. Analysis revealed that the type of activities and order most commonly adopted result in a more structured type of inquiry. Therefore, despite the spirit of the intended curriculum, the enacted curriculum is still balanced between traditional classroom activities and inquiry-oriented ones. This may not be surprising since change is not an instantaneous phenomenon but rather a process that can sometimes take longer than expected in order to achieve the goal. The complexity associated with implementation of change (e.g. Fullan, 2007; Ridden, 1991) contends that curriculum change is a process and not a single event, requiring ongoing support.

Consistent with the literature, there is a gap between teachers' claims about what they do and how they actually do things in practice, including implementing the curriculum. For example, according to Abd-El-Khalick, Boujaoude, Duschl, Hofstein, Lederman, Naiz, Treagust, and Tuan (2004), science teachers claim that they teach using inquiry methods, but when asked to give details of their enactment of inquiry they often provide a range of examples that can even be contradictory, indicating that science teaching style may differ among individuals attempting to implement the same approach within a single curriculum. This was also expected due to teachers' differing views of inquiry, and was found in this study.

Although it is acknowledged that there is no single model of inquiry-based science education to be followed, there are some widely recognized features of activities of both teachers and learners that are indicative of inquiry teaching and learning (Harlen & Allende,

2006). Highlighting the importance of using multiple teaching methods, Carin, Bass and Contant (2005) compared a teacher to a woodworker, arguing that just as one teaching method should not be considered sufficient for teaching all topics and meeting all standards, one tool cannot be sufficient to do every task a woodworker must complete. The NSES (NRC, 2000) point out that “there is no magic formula or recipe to follow in incorporating inquiry into classrooms and schools. Success requires creativity and sensitivity to a particular context and set of goals” (p. 144). In the present study this was confirmed, since in the attempt to implement inquiry in their daily practices, teachers did not follow the same route and were involved in a variety of activities. Those who believed that inquiry involved some form of practical work tended to focus on traditional inquiry activities, which are very structured and not open, and were combined with a more traditional type of activities.

Although traditional practices were still being used, it can be argued that the will to implement inquiry-based teaching was present, though the full shift had not yet been achieved. Of course this full shift was not the most expected but rather a good balance in combining teaching approaches would be most recommendable. The evident difficulty of having common ground on how to go about implementing inquiry in a classroom is a reality that is widely acknowledged. The literature suggests, with some variants, steps through which IBST is designed, and also provides evidence that even the science education research community still lacks sufficient empirical examples of inquiry instruction to which teachers would refer as models (Bybee, 2000; Enyedy & Goldberg, 2004). For example, Walker (2007) suggests a list of steps that includes (in this sequence), introduction, generation of investigation questions or a hypothesis, planning the experiment, conducting the experiment, interpretation of results, evaluation and adding relevance to the student’s life. However, the inquiry framework referred to by Cuevas, Lee, Hart and Deaktor (2005) seems to better guide teachers and students trying to learn and to use inquiry, and includes learners raising questions, pose hypotheses, research and experiment, analyse their data, and provide evidence-based explanations. In this study it was found that teachers carry out some inquiry activities, and when this involves an investigation they follow recognized steps allowing all learners to engage in specific activities.

It appears that when trying to implement this new science teaching approach, teachers involved learners in activities that fit in the inquiry continua of the degree of independence

the student has in asking and answering questions (Windschilt, 2000), ranging from confirmation to authentic inquiry through structured, guided and open forms of inquiry. However, it was found that more frequently when inquiry was adopted in the classroom, confirmatory or structured inquiries were more predominant than independent or open inquiries. To sum up, despite the emphasis given to inquiry in the new curriculum, it seems that it would be premature to argue that this curriculum is being fully enacted in the way it was intended. However, it signals that steps of inquiry as investigation are being followed in the science classroom, even though still with greater teacher direction.

Rwandan science education being a very recent enterprise, as presented in Chapter Two, may also impact on the ability to actually fully implement a desired change in the science curriculum, considering the current state of education in general and of science in particular. The next section discusses factors influencing these teachers' current practices and expands on reasons behind their practices associated with implementation of IBST.

Another purpose of this study was to find out which factors influenced teachers' practices with regard to implementation of IBST. Although the literature highlights that engaging students in inquiry is a common goal for science educators, it however acknowledges that many factors complicate the completion of such a task (e.g. Buck, Bretz & Towns, 2008; Fay & Bretz, 2008). The study revealed that there are many such factors, some contributing positively to the use of inquiry science teaching and others playing a negative role in terms of its implementation. In this study both type of factors were identified and discussed based on empirical data.

It was found that teachers' enjoyment of their job as attempting to implement inquiry was one of the major factors influencing their practices. Research has attempted to identify characteristics of teachers that enable them to embrace change and to be effective in its implementation. For example, the predisposition toward the change, including their beliefs, knowledge and perceptions were found to play a fundamental role in implementing any change brought into the curriculum. In the framework of curriculum implementation proposed by Rogan and Grayson (2003), the second construct related to the capacity to support innovation emphasizes teachers' factors. Level two of the profiles of capacity to support innovation highlights that the teacher enjoys his/her work, among others as for implementing change. The fourth level further indicates the teacher's willingness to change.

In this study the teachers' enjoyment of their job coupled with the positive attitude toward the change implying inquiry were found to positively influence teachers' daily practices with regard to implementation of IBST.

The national examination was seen also as a determinant of teachers' practices. As described in Chapter Two, after each level of the education system in Rwanda – and the O level in this study – learners are assessed and based on performance they shift between levels. Schools, learners and obviously teachers' performances are evaluated based on results in those types of exams. As a result, teachers strive to enact the curriculum with the concern of achieving this critical goal of having their learners obtain good results. The literature is also informative with regard to this issue. For example, Gibson and Chase (2002) in a study about the impact of an inquiry-based science programme on middle school students' attitudes toward science, found that “students who were taught using inquiry-based instructional method scored significantly higher on an achievement test than those who were taught using the traditional teaching approach” (p. 694). Similarly, Colburn (2000) and Davis (2001) support inquiry teaching as resulting in better test scores, described as “equal or superior to other instructional modes and results in higher scores on content achievement” (Colburn, 2000, p. 44). In this study teachers' actions were highly influenced by the examination concern, and through the data reported that teaching through inquiry prepared learners for the national examination. Unfortunately teachers report that they cannot use inquiry all the time due to lack of time to cover the examination syllabus. The implication is that if they had lots of time they would see inquiry as a positive means of preparing learners for examinations.

Furthermore, the NRC (2000) highlighted the importance of preparing teachers for inquiry-based teaching and the challenges they face, as well as the needs they should attend to for thoughtful and appropriate use of inquiry in their classroom. It argues that “for students to understand inquiry and use it to learn science their teachers need to be well-versed in inquiry-based methods yet most teachers have not had opportunities to learn science through inquiry or conduct scientific inquiries themselves” (p. 87).

In this study the role of teacher pre-service training to implement IBST was pointed out as having a positive influence on teachers' practices. However, it was also judged by teachers as being inadequate and therefore at the same time said to negatively influence their practices. The literature has evidenced that the inquiry practice of science teachers strongly

benefits from preparation programmes. However, the Rwanda science teacher pre-service training seems not to have a consistent model of preparing science student teachers to use inquiry-based instruction, like those proposed by the NRC (2000).

According to Wenning (2011), the effective use of scientific inquiry in the classroom is one typical characteristic of outstanding science teachers. However, despite the persistent encouragement of teachers to integrate inquiry in their daily teaching, the practice doesn't always take place in a sustainable way. Teachers acknowledge that it is difficult to implement inquiry activities in their curriculum despite the prevalence of worthwhile associated activities that offer students the chance to engage in scientific thinking (Fay & Bretz, 2008). The literature has identified a number of reasons that prevent teachers from effectively implementing inquiry in their teaching. Costenson and Lawson (1986) highlighted the inadequate preparation of teachers to use it as one of the chief reasons.

In this study the teacher pre-service training was also found by some teachers to be one of the factors negatively influencing their practices with regard to implanting IBST, while others saw it as the main foundation of their current teaching skills. The teacher pre-service training is criticized as not effectively tackling inquiry aspects. Wenning (2011) contends that "little attention is given in some teacher education programs to how the processes of scientific inquiry should be taught and acquired" (p. 2). You may find many science teachers who have never engaged in the learning of science through inquiry (Haefner, 2001), but whose curriculum requires them to make use of it. Given all these considerations, it would not be surprising that inquiry was not effectively implemented as expected with regard to the framework of this study. As a result of inadequate science teacher preparation, Wenning (2011) points out that:

Not all teacher candidates learn how to conduct inquiry and not all science teachers use inquiry in an effective fashion. Some in-service teachers do not employ it at all while others know it but do not know how to teach it. (p. 2)

Several barriers to using inquiry in science education have been reported. For inquiry to be successfully implemented, a variety of strategies aimed at mitigating those barriers should be put in place and were discussed in this study. Authors such as Colburn (2000), Ediger (2001) and Pierce (2001) have also analysed impediments to teaching science through inquiry. These included the fact that it is more time consuming, teachers' loss of control,

safety issues, teachers' uncertainty, lack of resources, teachers' perceptions that inquiry would work well with brilliant students, eventual student resistance to inquiry, teachers' lack of training and support, and the difficulty of assessment. These same reasons also fall under those discussed in the literature as constraints associated with failure to adequately use inquiry in the science classroom (Ackay, 2007; Anderson, 2002 & 2007; Bybee, 2000; NRC, 2000; Wee, Shepardon, Fast & Harbor, 2007; Windschitl, 2004 & Wenning, 2005b). In the present study the factors reported as negatively influencing science teachers' practices included, in addition to the teacher training, the lack of resources, heavy workload, class size and teacher's personal confidence. All of these elements were consistently found in the literature and fit into Anderson's (2007) three types of barriers that science teachers encounter when implementing a change, namely technical, political and cultural barriers (Johnson, 2006). The next section covers teachers' suggestions about which strategies should be adopted for better implementation of IBST.

One of the study's aims was to find out which interventions the teachers considered most appropriate for more effective implementation of inquiry in the classroom. Resources provision to schools and adequate professional development programmes (including reviewing and adapting the initial teacher training) were considered the most important interventions. Other strategies that teachers suggested included reducing teachers' workloads and providing a financial incentive in terms of salary increase and other financial support for IBST.

IBST and learning requires many skills and strategies, but more importantly its success depends on the availability of a wide range of resources, including some from beyond the classroom and the school. It is acknowledged that "nothing interferes with inquiry-based teaching more than lacking and adequate supply of instructional materials" (NRC, 2000, p. 149). The same source and many others in the literature highlighted issues associated with the availability of materials, kits and equipment as a major concern for better implementation of IBST in the classroom. In this study supplying resources to schools was identified as one of the main strategies for effective IBST implementation. However, it was revealed that in reality many schools are facing a shortage of adequate resources.

Given that the approach has been newly introduced, even existing textbooks are often not conducive for inquiry-based teaching. Therefore, with regard to effective implementation

of IBST a lot of effort is still needed to make it more efficient. The required support comprises, among others, providing a variety of support for staff including adequate professional development programmes. While the available professional development programmes still face considerable challenges, they are seen as playing a critical role in implementing curriculum change. For example, Supovitz and Turner (2000) contend that “although professional development may not have realized its potential, it is still seen as the best strategy for changing teaching practices” (p. 964). In this study it was found that professional development was the most relevant and appropriate strategy for better implementation of IBST. This may be due to the fact that the existing science teacher professional programme was felt to be inadequate.

To be of high quality, a professional development programme should incorporate at least six elements (Supovitz & Turner, 2000: 964-965) including: (a) immersing participants in inquiry, (b) being intensive and sustained, (c) engaging teachers in concrete teaching tasks, (d) focusing on subject matter knowledge and deepening teachers’ content skills, (e) being grounded in a common set of professional development standards, and (f) being connected to other aspects of school change. However, given the negative comments towards the training, I would assume that it does not meet these standards. An adequate and sustained professional development programme was pointed out as an intervention believed to positively contribute towards better implementation of IBST. It is well evidenced (see Supovitz & Turner, 2000) that staff development is central to almost every educational effort to improve curriculum implementation, especially when about implementing a change.

The important role played by effective professional development is that it enables teachers to overcome their constraints to using inquiry, even though it does not always result in changing practices as intended within official documents (Rushton & Lotter, 2011). In the context of this study, participants reported having limited support from professional development, which constitutes a significant impediment in implementation of inquiry-based science at lower secondary school in Rwanda, and opposed to the abovementioned quality standards of a professional development programme. The adoption and implementation of inquiry can only be achieved through adequate and well-designed professional development programmes, since it is widely acknowledged that many teachers display difficulties in teaching science through inquiry, because among other reasons they were not taught in such a

way nor exposed to it during their academic training (Kleine, Brown, Harte, Hilson, Malone, Moller, Niblett, Toole & Walker, 2002).

In the context of Rwanda, it can be seen from the above that IBST is not the main teaching approach, despite the curriculum policy emphasis. Teachers have two opposite viewpoints: some claim to use an inquiry teaching approach for the advantages it provides to both learners and the teacher, while others do not apply it for various reasons. Among those who reported not effectively implementing an IBST approach, the most common reasons reported were lack of confidence in its use, shortage of materials, and the curriculum being too long. Some of these reasons are also found in the literature as problems that teachers associate with use of inquiry-based science and that hinder its implementation (Costenson & Lawson, 1986; Eick & Reed, 2002; Deters, 2005; Keys & Bryan, 2001). On the other hand, the positive aspects of inquiry-based teaching and learning are also recognized, such as the promotion of problem-solving skills (Ediger, 2001), development of higher-order thinking and scientific reasoning skills (Leonard & Penick, 2000; Melear, 2000), confidence in independent learning, curiosity, enthusiasm and confidence, and good communication skills as well as lifelong science learning (Davis & Irwn, 2001; Chin & Kayalvizhi, 2002; Linn, 2000; Melear, 2000). Summing up, it seems that Rwandan teachers are experiencing the same issues that other teachers have reported in various studies.

Although an effective professional development programme is undoubtedly necessary to support successful implementation, the success of various inquiry-based professional development programmes depend on a range of factors, and teachers need more than training. However, for a professional development programme to be of significance for teachers they need to experience inquiry first-hand as part of their professional development, because one of the critiques of science teacher education is that today's teachers learned science from textbooks that are inconsistent with an inquiry approach (Punuel, Fishman, Yamaguchi & Gallagher, 2007).

The NRC (2000) asserts that to foster the changes in teaching required by inquiry-based approaches, administrators and other leaders have to provide a wide array of support, without which the endeavour would be unlikely to succeed or be sustained. Such support includes, among others, making material and equipment available and providing teachers with opportunities to learn, moral support and encouragement of any sort. However, it was a

bit surprising that the administrative assistance and support was not seen as valuable by teachers, despite its potential role, since school principals are considered to be essential links in the adoption of inquiry as a way of teaching and learning.

Implementing a change is not an easy task and successful change requires change to the human system. In this study there were many indicators that change concerning inquiry implementation fits a traditional and adaptive change theories to some extent. The three strategies of traditional change theory namely empirical-rational, power-coercive and normative-reeducative strategies apply in the study. For example, data indicate that teachers understand the logic and benefits for the change from the comments made and were positive about the need for change (sub-assertions 2a & 2b). The coercive strategy of the traditional change theory also filters through as it was compulsory to implement the curriculum as intended which requires an inquiry approach. The normative re-educative strategy reflects in the teachers' commitment and need to be engaged in the process of change which was revealed through the support they expressed they would like to be provided with for a more effective implementation of IBST (sub-assertion 5a). While it is acknowledged that change does not come by simply providing information as in the empirical rational strategy (Quinn, Spreitzer & Brown, 2000), in order to achieve a real adaptive change, further actions should be taken to sustain change and this was the object of Section 6.3 of this study.

It was found that there is a close interrelationship between teachers' practices, factors influencing these practices, and strategies for more effective implementation of IBST. These strategies were to some extent aimed at correcting the factors reported as having a negative influence and reinforcing those with a positive influence. The next and last chapter summarizes the findings of the study and discusses its implications for Rwandan science education in general and that at lower secondary school in particular.

CHAPTER SEVEN

SUMMARY, IMPLICATIONS AND CONCLUSION

The main purpose of this study was to describe, discuss and analyse Rwandan lower secondary school science teachers' responses to the introduction of IBST in the science curriculum. More specifically, the study tried to unpack this phenomenon through five foci, namely: the science teachers' understanding of IBST; their attitudes towards the introduction of inquiry into the science curriculum; the practices and activities they were engaged with in the science curriculum with regard to IBST; factors influencing their current teaching practices; and their perceptions about which strategies should be adopted for more effective implementation of IBST.

In carrying out this study I worked within a pragmatic paradigm and adopted a sequential explanatory mixed-methods design. This involved a two-phase sequential process of collecting data by means of a survey questionnaire administered to 150 science teachers followed by interviews with 15 teachers. Analysis of the first set of data involved statistical analysis to generate frequency tables which were interpreted according to the nature of the data, both descriptive and inferential where appropriate. The second phase generated data in the form of transcribed text from interviews and personal observations, which were inductively analysed to determine participants' views in more depth and to validate trends that were quantitatively established. Findings from the two sets of data were then connected and integrated for the purpose of reporting and answering the research questions. Figure 7.1 gives a picture of the study's components and their interconnections.

The main purpose of this chapter is to firstly provide a summary of the findings and secondly discuss the implications of the study. The concluding section of the chapter discusses a number of practical recommendations for further research as well as some of the limitations of the study.

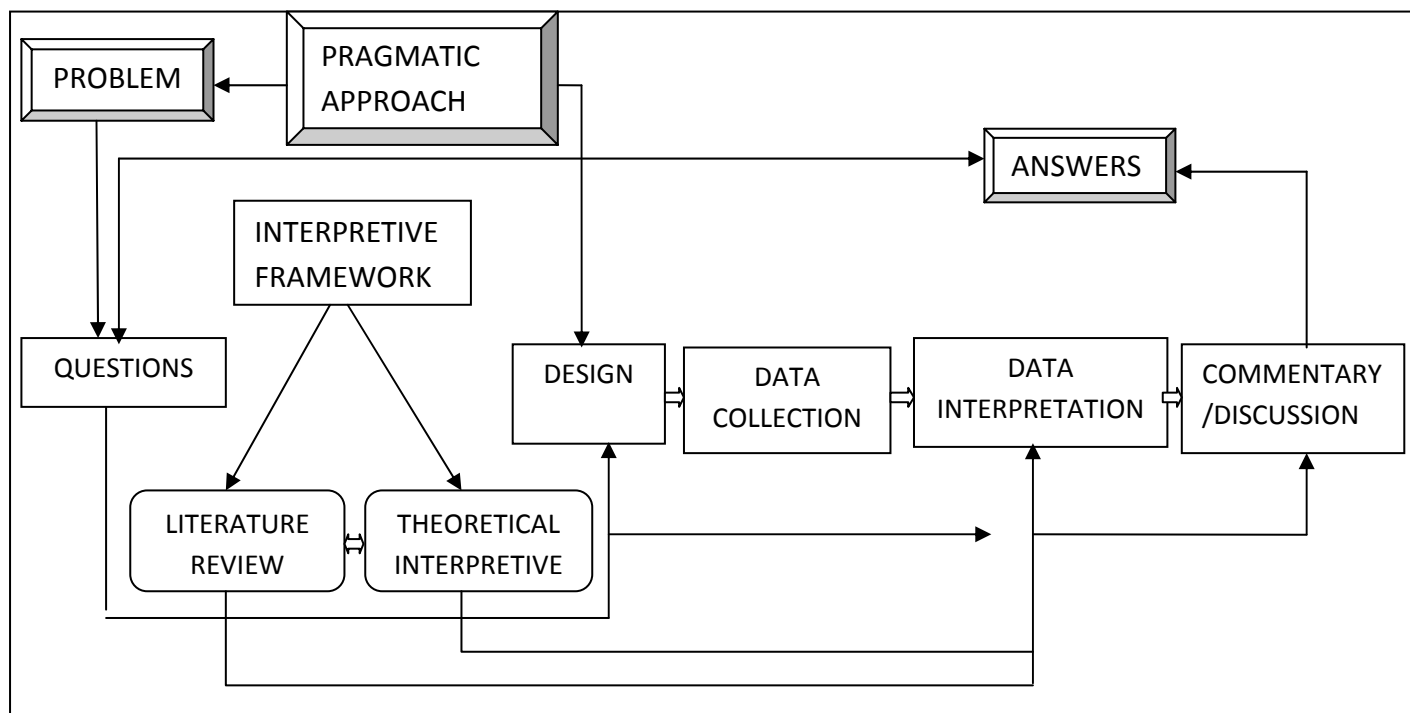


Figure 7. 1. Summary of the components of the study

7.1. SUMMARY OF FINDINGS

The findings of a study are closely related to the answers to the research questions. In the case of the present study these findings were expressed in the form of empirical assertions (Gallagher & Tobin, 1991) and were generated based on the two sets of data. Each assertion was associated with a number of sub-assertions, which provided the detailed answers required to support the main assertion. Since the study had five specific research questions, five assertions were generated. What follows is a summary of the assertions and discussion presented in detail in Chapters Five and Six of this thesis. In order to see the ‘big picture’ of the study they are summarized in the diagram in Figure 7.2.



Figure 7. 2. Summary of links of assertions to research questions

7.1.1. Teachers' understanding of IBST

In response to the question about the science teachers' understanding of IBST, the study revealed that teachers who participated in the study had varying understanding of what IBST is. As summarized in assertion 1, *“teachers associate inquiry teaching with a number of its common characteristics such as learner-centred teaching and practical work. However, a minority of teachers do not have accepted understandings of inquiry teaching”*. Specific claims aimed at answering the corresponding research question were made through the associated sub-assertions: (a) the most common characteristic of IBST was some form of activity involving practical work; (b) teachers associated learner-centred teaching and teachers acting as facilitators with inquiry-focused teaching; and (c) some teachers do not have an understanding that matches that of the curriculum or general community of educators.

Instead of providing a full definition, teachers highlighted the more common activities that take place as a result of implementing IBST in a classroom. For example, they see it as a teaching approach that focuses on activities involving practical work, including experiments and hands-on activities in the form of investigation, referring to a learner's active participation and the facilitating role of the teacher. This was an indication that in their view inquiry requires a more learner-centred approach, which was further detailed in response to the question concerning teachers' practices and activities when using inquiry teaching. However, it was found that some teachers (nearly 10%) do not have an understanding of inquiry that matches that of the curriculum or general community of educators.

It was felt that these findings were not surprising, given the variety of meanings found in the literature, which acknowledged the variety of interpretations of the concept of inquiry given people's differing worldviews (e.g. Wheeler, 2000). For example, it was reported in some science education literature that there seems to be a common, ill-informed understanding among science teachers that inquiry learning is all about hands-on science activities (Atar, 2007). In the context of the present study this was even more understandable due to a number of factors. A possible explanation for this finding was associated with the fact that science education is a young discipline in the history of education in Rwanda, and inquiry was introduced only very recently in the discourse of science education. Another possible explanation was based on the data itself, as it was found that teachers were not fully

involved in the process of revision of the curriculum and not adequately prepared to embark upon an inquiry teaching approach.

7.1.2. Teachers' attitudes towards inquiry-based teaching and learning

Assertion 2 was related to the second research question, concerning the teachers' attitudes towards the introduction of IBST into the curriculum. *In general, teachers were positive toward the introduction and implementation of IBST. They agreed that there was a need to change. They were reasonably positive about their ability to implement the new curriculum and stated that the change had brought about improvements in their teaching and learning.*

Breaking down this main assertion generated the following sub-assertions: (a) teachers agreed that there was a need to change from the old curriculum, based on traditional teaching, toward an inquiry-based curriculum; (b) teachers had mixed feelings about the new curriculum – some were positive and confident about their ability to implement inquiry as required by the new curriculum (most common reasons for positive views were associated with the perceived benefits of inquiry) – and those who were not confident mainly reported, among other reasons, their lack of training and the poor conditions in schools; (c) teachers indicated that teaching through inquiry has resulted in improvement of a number of aspects of teaching and learning, such as learners' increased participation and collaboration with classmates; and (d) teachers considered the current trend toward inquiry teaching as positive and holding promise for the future of science education.

For any change to be effective it is vital that actors of its implementation – in this case teachers implementing inquiry – have positive attitudes in conjunction with other elements, such as their beliefs and practical knowledge of inquiry (Choi & Ramsey, 2008). Although instructional strategies and practices can be impacted on by a teacher's attitudes toward the particular subject taught, in this study this finding did not necessarily guarantee that they were effectively implementing an inquiry teaching approach. In this study the attitudes that teachers displayed were associated with acknowledging the potential benefits of inquiry as supported by the literature (e.g. Anderson, 2007).

With regard to implementation, teachers had mixed feelings about the new curriculum. Some were positive and confident about their ability to implement the new curriculum, with most common reasons for their confidence associated with benefits of inquiry. Those who were not confident mainly reported, among other reasons, the lack of training and poor conditions in schools. They were reasonably positive about their ability to implement the new curriculum and reported that the change has brought about improvements in their teaching and learning. They further indicated that teaching through inquiry has resulted in improvement of a number of aspects of teaching and learning, such as learners' increased participation and collaboration with classmates. Those benefits reported in this study, together with the areas teachers felt have improved as a result of implementing inquiry, were also found in the literature. Finally, teachers considered the current trend toward inquiry teaching as positive and holding promise for the future of science education in Rwanda.

7.1.3. Teachers' practices with regard to implementing IBST

Inquiry-based science instruction requires the use of different tactics, methods and strategies; one should not be misled as to expect a single, prescribed way of delivering inquiry-based science lessons. The answer to the question about which activities teachers use when attempting to implement inquiry teaching is summarized in assertion 3 and its associated sub-assertions. It was found that teachers in their daily practices use both traditional and inquiry-oriented types of activities. It is claimed in the assertion that *“according to the teachers, traditional classroom activities were more frequently used than inquiry-based activities. However, when teachers included inquiry in their teaching they generally followed a specific order of activities. These activities indicated a more structured than open-ended type of inquiry”*. Details in answering the research question led to breaking down this main assertion into the following two sub-assertions: (a) in their daily teaching, teachers reported that traditional classroom activities were used more often than more inquiry-based activities; and (b) when teachers engaged in an inquiry teaching approach, the activities they reported doing resulted in it being mostly a structured and closed form of inquiry. This was an indication that inquiry-based strategies are not the only ones used in their classrooms and teachers continue to use structured traditional forms of practical work. Findings from the study reveal an apparent gap between the intended and implemented

curriculum and it appears (given a lack of initiatives) as if teachers alone are expected to close that gap. However, effective narrowing of the gap between the intended and the implemented curriculum requires that curriculum designers and those responsible for implementation should be selecting appropriate implementation methods to help teachers to change (Sahlberg, 2006).

Not only in Rwanda but also in other countries particularly from Sub-Saharan Africa, various reports indicate that there is a huge gap between the intended curriculum and what is actually implemented in the classroom (Ottevanger, van den Akker & de Feiter, 2007). Among other reasons reported are the lack of teaching materials and other resources, overloaded curriculum and lack of teachers' confidence with the subject matter. These reasons were also pointed out from this study. The gap can be understood in terms of three dimensions that Fullan (2007) contends should be considered: (a) the possible use of new or revised materials such as curriculum materials or technologies; (b) the possible use of new teaching approaches, including new teaching strategies or activities; and (c) the possible alteration of beliefs, including particular new policies or programmes (p. 30). These three dimensions need to be taken into account for the intended outcome to be achieved.

In the case of Rwanda, the gap exists possibly for the following reasons: Firstly, even though new materials and texts were provided and training took place, not all teachers felt they were sufficient and they also reported that the coverage was limited. Secondly, the new approach of inquiry was not fully implemented as many still stuck on traditional teaching approach. Thirdly, despite teachers expressing a willingness to move toward an inquiry approach underpinned by constructivism from a traditional approach but they reported a number of reasons which prevented them from using inquiry more often (sub-assertion 4b). The gap exists most probably not because of factors associated with the curriculum itself but because the above dimensions were not fully considered in implementation.

As it was pointed out earlier, a range of benefits and areas of improvement were identified by the introduction of inquiry, but analysis of teachers' practices and activities indicated they did not translate them into effective inquiry teaching implementation. It was therefore necessary to seek answers to the next two research questions, concerning respectively the factors influencing their practices and the strategies teachers considered most relevant for promoting IBST.

As Harste (1993) reported, when education is viewed as inquiry, important things happen and the focus of education becomes learning while the task of teaching becomes that of supporting the inquiry process. Among those things happening, the study revealed that the sequence of activities that teachers tended to follow when applying inquiry strategies appeared to match those suggested by the IPA (2010) that were identified as part of the framework of this study. They are also informed by the literature. For example, Leonard and Penick (2009) provided a comprehensive summary of activities describing the important role of both teachers and learners in inquiry teaching and learning. The study revealed that the sequence of activities used results in a more structured form of inquiry, with the responsibility for the inquiry shared by both learners and teacher. This sequence that teachers followed leading to a structured type of inquiry fits within the general syntaxes of the various levels of inquiry proposed by Wenning (2010), at the lower level of inquiry, indicating that implementation of inquiry in Rwanda lower secondary science schools still needs to be broadened so that the whole spectrum of inquiry is covered.

This finding goes along with literature which has highlighted the lack of a single model of inquiry-based instruction (e.g. Harlen & Allende, 2006) and lack of agreement as to what constitutes inquiry in the classroom (Barrow, 2006). Even the NSES (NRC, 2000), referred to as part of the study's inquiry framework, pointed out the lack of a common recipe to follow when incorporating inquiry into the classroom. Therefore, teachers may go through a variety of activities purported to be inquiry-oriented, but which in reality do not fit into any inquiry framework or model of science teaching.

7.1.4. Factors influencing teachers' practices in inquiry teaching implementation

The implementation of inquiry in the classroom and related practices of teachers are influenced by a variety of factors, some with a positive influence while others impede it. As a result of data analysis and in an attempt to answer the research question about factors influencing teachers' practices that they associate with inquiry, it was claimed in assertion 4 that *“teachers' inquiry practices are influenced positively by some factors, such as meeting examination demands and enjoyment of teaching through inquiry, and negatively influenced by other factors, such as lack of teaching time, resources for practical work and confidence*

associated with inadequate training”. This assertion was then broken down into two sub-assertions, namely: (a) the most common factors that positively influence teachers’ practices in implementing an inquiry teaching approach are the belief that it prepares learners for examinations and the fact that they find it an enjoyable instructional method; and (b) teachers reported a number of factors negatively influencing their practices with regard to implementing IBST, most frequently indicated as teaching time, resources for practical work and confidence associated with inadequate training.

During the IAP international conference about taking inquiry-based science education into secondary education (IAP, 2010) it was pointed out that introducing inquiry-based science education into secondary school is not a straightforward process. The science education literature suggests that there are as many barriers to the infusion of inquiry into the science classroom as there are ingredients for making inquiry an integral part of teaching and learning (e.g. Ackey, 2007; Anderson, 2007; Bybee, 2007; Johnson, 2006). In most cases teachers acknowledged the importance and value of IBST but faced difficulty in implementing it as a result of those barriers.

These factors identified by teachers in this study as influencing the implementation of an inquiry teaching approach were also reported in other studies that attempted to investigate the reasons why inquiry is not widely implemented, and the origin of not using inquiry-based science instruction properly (e.g. Anderson, 2007; Kerlin, McDonald & Kelly, 2009; Wee, Shepardon, Fast & Harbor, 2007; Wenning, 2005b). However, in the case of Rwanda where the study was based, resources and teacher training were reported to be the most critical factors.

Acknowledging the critical role of the teacher in implementing the curriculum, this study revealed a hope of overcoming the many obstacles to implementing an IBST approach, since one of the major positive factors was the teachers’ personal enjoyment of teaching through inquiry. As for the impact of tests and examinations, which were also reported to have a positive influence on implementation of inquiry, the finding corroborates those of other research, as it is well documented that all assessment, to some extent, influences what is taught (IAP, 2010, p. 13). In the Rwandan context, it is a common experience that results of tests and examinations are used to set targets for teachers and schools, and therefore influence teachers’ practices in terms of implementing the intended curriculum. Unfortunately teachers

report that they cannot use inquiry all the time due to a lack of time to cover the examination syllabus. The implication is that if they had lots of time they would see inquiry as a positive means of preparing learners for examinations. This may be understood considering the impact that examinations have on teaching and learning process in many countries. As pointed out by Ottevanger, van den Akker and de Feiter (2007), “there is a lot of ‘teaching to the test’ where teachers focus on topics and skills that are included in the examinations and devote a lot of time to acclimatizing students to examination-type questions” (p. 19).

7.1.5. Strategies for more effective IBST implementation

In response to the last research question about strategies teachers think would be of use to promote and improve IBST implementation, assertion 5 was generated. It was claimed that *“teachers agreed upon a number of interventions which would make the implementation of inquiry in the classroom more effective. They do not isolate one particular intervention but rather a combination of many, the most frequently mentioned being resources provision and professional development”*. This assertion was broken into two sub-assertions in order to be more explicit about the most important interventions: (a) teachers agreed that a number of initiatives could be implemented in order to make inquiry teaching more effective, where improvement of resources provision was perceived as the most relevant intervention; and (b) teacher professional development was an important factor for more effective implementation of inquiry in schools, as they felt that both pre-service and in-service teacher training was not very adequate.

Apart from these two major strategies, teachers reported other interventions that they thought would also contribute to making IBST more effective, such as reducing teachers’ workloads, giving financial support, and training principals so that they can provide more management support. All of these strategies that teachers reported as ways of improving implementation of an inquiry-based teaching approach were seen as ways of addressing the factors identified as negatively influencing the teachers’ practices with regard to inquiry implementation. Furthermore, the science teacher training curriculum should establish a model for implementing inquiry-based instruction. In fact, my experience with Rwandan

science teacher preparation is that there is as yet no model for preparing prospective teachers to use inquiry-based instruction.

7.2. IMPLICATIONS OF THE STUDY

This study has highlighted teachers' responses to the curriculum change in introducing an IBST approach into the lower secondary school science curriculum in Rwanda. The lower secondary science curriculum in Rwanda advocates the use of inquiry as part of several teaching strategies. Figure 7.3 illustrates the existing model of implementing inquiry within the Rwandan educational structures. As can be seen in this diagram, inquiry is introduced in the classroom by the organ in charge of designing the curriculum which operates under the authority of MINEDUC through the REB. Its implementation is made possible by teachers who are initially trained by teacher training institutions and thereafter provided with in-service training through professional development programmes. Within this structure, inquiry is either practiced or not, and in this last case traditional activities such as direct teaching predominate. When implemented, it either involves inquiry-oriented activities or a mix with traditional teaching approaches. The study revealed that when teachers implemented inquiry, given their knowledge and conditions, they ended up with a particular version of inquiry which is more structured and guided. If they do not use inquiry, only traditional activities such as direct teaching or verification practicals take place.

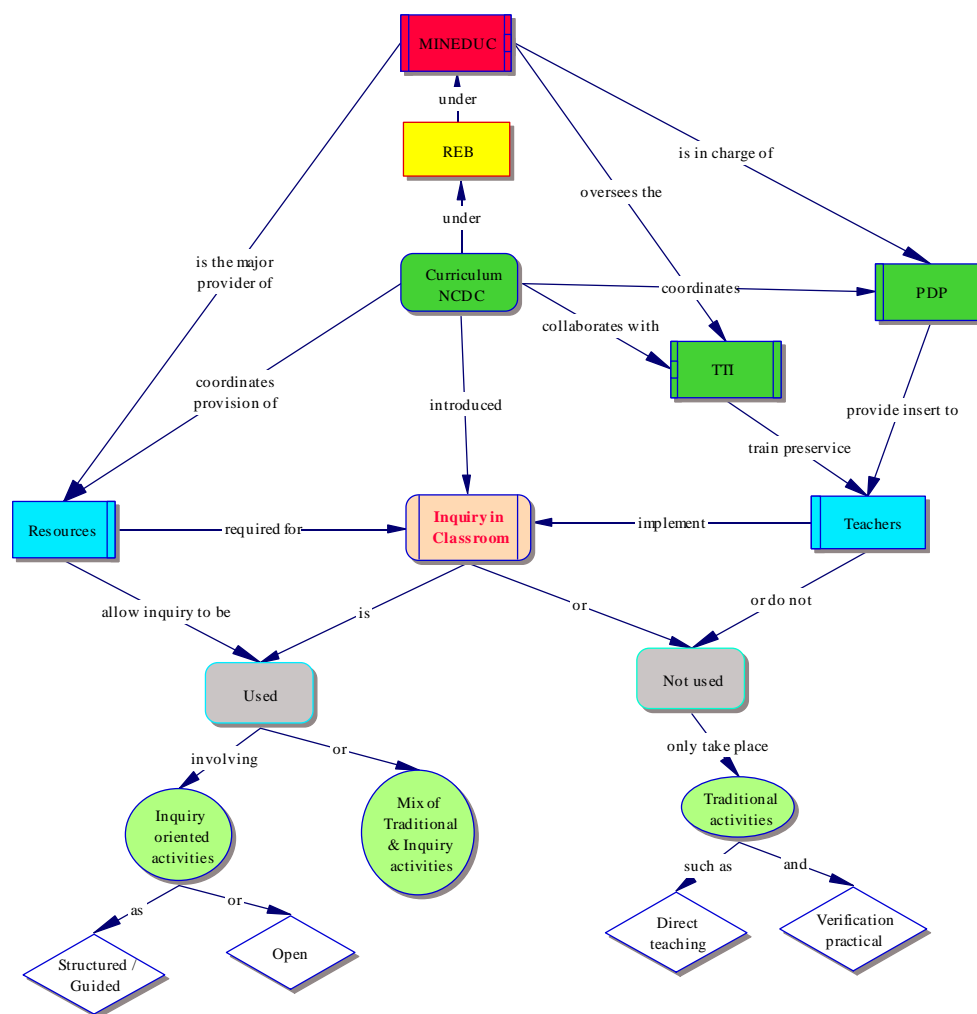


Figure 7. 3. Existing model of implementing inquiry in Rwanda

(TTI = teacher training institutions, PDP = professional development programmes)

Based on the findings, this study has implications at various levels. Apart from its contribution to the body of science education literature, I believe that the study has implications for science teacher professional development and educational management, particularly the curricula and pedagogical material development unit of the MINEDUC. These implications are discussed in the following paragraphs.

7.2.1. Implications for science education

As stated in the introductory chapter, this study is among very few that have been conducted in the field of science teaching and learning in Rwanda, and probably the first to focus on lower secondary school. In this study participant teachers displayed their

understanding of IBST. The study revealed that teachers had varying understandings, and that the structured version of inquiry was predominantly taking place. From this study, teachers' understandings may be an indication of the way IBST was implemented. This suggests that there is a need for teachers to be more familiar with the role and function of inquiry, since it is well evidenced that among other factors, understanding of scientific inquiry is seen as a prerequisite for implementing inquiry-based instruction in the classroom (Wenning, 2005b).

However, whether teachers' understanding is complete or partial, implementation should not be postponed or set for a later stage after all associated problems are resolved. Not only in Rwanda but any country, if curriculum change is adopted and the decision for its implementation is taken, this should not be held back until all conditions are met. The process should rather be started, with awareness of the need to attend to all unresolved issues until there is a better match between the intended and implemented curriculum.

This study identified a number of issues that teachers reported as strategies for more effective implementation of inquiry. To that end, teachers should be encouraged to start implementing inquiry-based teaching despite inherent difficulties associated with its use, since it is only with experience coupled with a full commitment to embracing the change that the skills needed for better implementation of inquiry-based science instruction can be acquired. Teachers should then be provided with supportive and practical help, enabling them to incorporate inquiry activities in their lessons. This not only helps teachers to gain enough experience for more efficient implementation and management of inquiry-based science lessons, but also helps learners to develop and sharpen their inquiry learning skills.

I believe that more frequent use of inquiry-based lessons would help teachers to adopt inquiry science in their daily practices instead of considering it as an add-on activity. In so doing, the three facets of inquiry, as a style of teaching, a style of learning and a way of doing science in a classroom setting in a harmonious interrelation would be achieved. Therefore, the more teachers that implement inquiry-based lessons, the more knowledgeable they become in the inquiry science teaching approach.

In this study it was found that teachers were involved in inquiry activities which were limited to the most structured type of inquiry. This was not unexpected, due to inquiry having been introduced very recently. It is also expected that with time and opportunity to practice, significant change will be brought into science teachers' practices, especially once supported by the adequate inquiry-based professional development which is not currently present. This

has been proven to significantly change teachers' use of inquiry-based teaching practices (Supovitz & Tuner, 2000). Findings from this study suggest that changes in the teachers' attitudes have taken place within the implementation of the new curriculum focussing on inquiry.

The majority of teachers reported that teaching resources would indisputably help to make the implementation on IBST more effective. In contrast, Earnest and Treagust (2001) for example found that most teachers in Rwanda did not perform any laboratory work and were unaware of the didactic and organizational problems related to the use of laboratory equipment. They also found that the availability of laboratory equipment might not change their style of teaching, because of overcrowded classes, infrequency of practical lessons, and lack of physical space in schools. This situation is common to developing countries (Gado, 2005).

When teachers reported on their preparedness for implementing inquiry and the areas they would like to focus on if an in-service programme was provided, the matter of science content was predominantly reported. This has been found in previous studies – a weak background in science negatively impacts on the teachers' confidence, and may delay their efforts to implement inquiry-based lessons (Lee, Hard, Cuevas & Ender, 2004). Based on findings from the current study, it was suggested that a professional development programme be put in place aimed at providing teachers with a clearer understanding of inquiry, its place in teaching and learning and within the curriculum, as well as its implication for examinations, which were found to influence the way teachers go about integrating inquiry in their daily practices. Pre-service science teachers' training should also review the curriculum, aiming at training teachers who would be able to fit within the school curriculum requirements, examination demands and adaptation for adoption of any change brought into the curriculum. This may result in an improvement in science teachers' understanding and investigation of a way of setting a model and operational definitions to enable teachers to implement IBST. For example, the seven-steps of inquiry learning process (Short, 2003) can be referred to at pre-service level and used as a common, country-wide model to generate common understandings. Given the dynamic nature of curriculum, every change in the school curriculum should not result in teacher education curriculum change unless it is a change at macro level (Carl, 2009). In other words, the teacher education curriculum would change accordingly only when there is a philosophical change brought into the school curriculum. In

the case of inquiry, it impacted only on the O level science grades, hence not requiring a major change in teacher pre-service education since general inquiry teaching has always been part of science teacher training. Rather a particular emphasis should be put on an adequate professional development programme for teachers in-service focussing on implementation of inquiry at those particular grades where it is now emphasised.

7.2.2. Implications for educational management

The findings of this study inform the educational management bodies about the prevailing situation with regard to the lower secondary school science curriculum and particularly about the implementation of an IBST approach. Having identified factors that hinder its implementation and strategies that teachers consider to be the most appropriate for a more efficient implementation of this teaching approach, the study informs education administrators about the most relevant interventions and necessary support to promote IBST. For example, the study may provide valuable information to the examination and accreditation unit on adjusting the type of examination so that it matches with what is actually taking place in the classroom, since concern with the national examination was identified as positively influencing teachers' practices with regard to inquiry teaching implementation.

Consistent with the science education literature, this study identified a number of obstacles to successful integration of inquiry in the classroom. Therefore, based on the study's findings, all stakeholders in their respective areas of responsibilities could provide the necessary input aimed at alleviating the impact of these obstacles and thus facilitating the integration of inquiry into school science. In particular, schools should be provided with resources to match curriculum demands and requirements. To this end, the relevant organs of the MINEDUC must undertake a resource analysis of the curriculum, i.e. of what resources are required to implement the new curriculum as intended. Based on that analysis, it should then provide schools so that all teachers have the resources to do what is expected in the curriculum. Although the MINEDUC seems to have the full responsibility of resourcing schools, all educational stakeholders are concerned, given the variety of schools' status. Therefore all educational stakeholders should play their roles and combine their efforts to

ensure that all schools are provided with the minimum of required materials and equipment without which IBST and learning are unlikely to be sustained.

The study is informative to school administrators as to the kind of support they can provide to promote inquiry-based instruction. As the study also contributed to identifying issues and potential impediments, it constitutes a reference for educational managers in charge of implementing educational policies in any attempt to make necessary changes to facilitate integration of inquiry into school science.

7.2.3. Implications for science teacher professional development

According to Anderson (2002), internalizing and putting reform ideas into practice is not an easy task for many teachers. As evidenced in this study, teachers still use traditional teaching approaches, and when they attempt to make use of inquiry they appear to remain at a level of a structured and guided type of inquiry, despite their will to use inquiry and a positive attitude toward its introduction into the curriculum. The literature (e.g. Loucks-Horsley, Hewson, Love & Stiles, 2003) together with the findings from this study highlight the role of teacher professional development as a proposed method to support practicing teachers in implementing inquiry-based instruction in science. The study revealed that many teachers reported that they were inadequately prepared to teach science using an inquiry approach, since the pre-service science teacher training was criticized for not explicitly focusing on inquiry. This study will therefore inform training providers about the most relevant type of professional development programme to be put in place. It is documented (e.g. Capps & Crawford, 2009) that in-service programmes which immerse teachers in authentic inquiry are more likely to enhance teachers' knowledge, prepare teachers to implement inquiry instruction and therefore lead to enhanced learners' understanding.

Teachers involved in this study expressed the strong belief that a well-designed professional development programme is essential to enable them to implement IBST effectively. This finding is consistent with the literature. For example, in a critical review of research on the effectiveness of professional development models related to inquiry, Capps and Crawford (2009, p. 12) concluded by arguing that:

If teachers are going to be asked to teach using inquiry approaches they will need to be comfortable with science content knowledge, understand what inquiry is, have experience both in conducting scientific inquiry and teaching using inquiry-based approaches, and have practice adapting lessons to be congruent with inquiry-based instruction.

It is obvious that this can only be achieved through an adequate professional development programme. In this regard, Wenning (2005b) highlighted the critical role of salient and prolonged professional development activities for obtaining teachers who will successfully implement inquiry-based science instruction. This would promote a juxtaposition of science teachers' beliefs and knowledge of teaching science as inquiry against the reality of what happens in practice (Crawford, 2000). This would also enable teachers to balance use of a more structured and the more open form of inquiry.

Research on science teacher education has shown that there is a shortage, especially at individual developing country level, of systematic attempts to trace the products of science teacher education through schools and evaluate the adequacy of their training. As the present study involved practitioner teachers, it may have additional implications for education planners, in identifying what kind of science teacher education system is most appropriate and efficient, considering that "whereas curriculum change has been rapid in many school systems, much less change seems to have taken place in pre-service training approaches" (Lewin, 1992, p. 156). In the case of Rwanda this unbalanced situation was also reported as a finding of this study, and in my personal first-hand experience as a science teacher educator I have also witnessed this; particular attention is therefore required to reduce this gap.

7.3. LIMITATIONS OF THE STUDY

While this study was an attempt to bring together several constructs related to IBST and learning, with particular emphasis on teachers' responses to the introduction of this new teaching approach in the lower secondary school science curriculum, it provides only a snapshot of the prevailing situation in terms of inquiry implementation. The study has specifically looked at science teachers' responses to the introduction of IBST at lower secondary school in Rwanda. This new approach of teaching science is not, however, the

only way of implementing the revised curriculum. While the focus in science is on inquiry, the new curriculum also encourages other new general instructional strategies, such as discovery learning methodology and active group methodology. The choice of methods was left very much in the hands of individual teachers. Therefore, the first limitation is that the study focused on teachers' responses to only one aspect of the new innovations in the science curriculum. Also it focused on one level of secondary school only, while reforms are being made at various levels of schooling, including primary and upper secondary school.

Although every attempt was made to be representative, it was not possible to involve all science teachers, even though precautions were taken in selecting participants representing all types of teachers from all kinds of schools countrywide. Therefore, the limitation associated to coverage aspects appears to be a reality in this study, although this is often inherent to any research of such a large scale. The study is also mostly based on teachers' views, and very little on concrete observations of actual practice, such as prolonged classroom observations, analysis of learners' books or assessment and examination style analysis. This suggests the need for carrying out further studies, and to look for this type of evidence and see whether what teachers say they are doing is actually being done, and the extent of its effectiveness.

I further believe that there would be greater confidence in the validity of future findings if a study was extended over a relatively long period of time, to allow the researcher to follow the changing circumstances of teachers while implementing the new teaching and learning approach. What has been reported is the situation after three years of implementation, and this could change as teachers become more aware of inquiry through in-service training and become more confident in implementing it.

Since the revision of the science curriculum has taken effect only since 2007, no research had yet been done into its implementation at the time of commencement of this study, and probably until now. In no way is this study attempting to fully present all relevant and influential factors contributing to the improvement of teaching and learning of science in Rwanda. It attempts, however, to contribute to the small but growing body of literature in the field and, more importantly, serves as a platform for further research. Therefore, this study seems to be a 'door-opener' to more research, since it leaves a number of concerns and several unanswered questions with regard to teaching and learning of science in Rwanda –for

example, issues such as the nature of assessment tools that can help encourage the implementation of inquiry.

7.4. CONCLUDING REMARKS

According to Lewin (1992), there are many different approaches to the teaching and learning of science, and a massive body of literature on the subject. Similarly, inquiry has many forms and is controversial, since both educators and researchers have different views of inquiry. In its essence, inquiry-based teaching engages learners in investigations to answer questions. However, for the purpose of this study the form of inquiry that was expected to be seen implemented was that proposed and encouraged by the new science O-level curriculum in Rwanda, which is a learner-centred approach that has main components including scientific investigation whereby learners identify or are given a question to be investigated, then observe and predict, devise ways to obtain and analyse data, discuss the meaning of their data, and experience and finally communicate their findings and ideas with colleagues.

Based on the study findings, it seems that teaching still has further to go in moving from traditional ‘chalk and talk’ science education to science education that promotes inquiry, where learners ask or formulate questions themselves and gather evidence from various sources to answer those questions. Teachers in this study displayed a variety of understandings of inquiry, on which they based their practices. Teachers recognized the power and potential benefits of inquiry, but at the same time pointed out a number of factors that prevented them from effectively implementing it in their daily practice. Time to do inquiry, resources and personal confidence were the issues most commonly highlighted.

The teachers suggested that an adequate professional development programme and provision of resources constituted the key pillars for effective IBST implementation. A finding from the study that had a potential effect in motivating teachers in the way they went about implementing the curriculum were concerns about examination. As Horner (2012) suggested, “if scientific inquiry is inextricably linked to knowledge and understanding, the assessment needs to find ways to test this. If not, inadequate assessments will continue to inhibit teaching and learning” (p. 14). According to teachers, the assessment and examination

component was influencing their practices. My personal experience, furthered by the teachers' reports, indicates that teachers are still under ever-increasing pressure of achieving a high pass rate for their learners in the national examination, regardless of a particular teaching approach. Sometimes the public, including administrators and parents, are more interested in learners' exam scores than their scientific literacy, and this may lead teachers into the dilemma of either teaching for tests and exams or teaching science through inquiry strategies which may not necessarily meet the requirements of existing types of examination.

Although teaching science through inquiry has been strongly recommended and encouraged in many parts of the globe, teachers do not feel that they are equipped enough with the skills and experience required to integrate inquiry in their science instruction. This was found in this study, as teachers expressed mixed feelings about their confidence in using inquiry. The expected shift from a traditional to an inquiry-based teaching approach being a process rather than a simple, once-off event, it was obvious that teachers would still be struggling to fully implement the new change brought into their existing practices, and this was confirmed by the findings of the study. It is well documented that teacher change is difficult. This study has again reinforced the emerging consensus from the literature that bringing about curriculum change – especially when it comes to changing the way teachers work in the classroom – is complex.

Just as in the statement that “not all that glitters is gold”, “not all science teaching is authentically inquiry oriented even though that might be the intent” (Wenning, 2011, p. 2). Leonard and Penick (2009) reviewed the literature and attempted to provide a working definition of inquiry in the classroom, and suggested which activities both teachers and students get involved in a “true inquiry-based science classroom” (p. 25). There is therefore a need to move beyond the curriculum design and to set a protocol or model of its implementation. This would involve clearly defining the steps and actions which should be referred to as a guideline for IBST implementation in the context of Rwanda, because there is one science curriculum, but teachers showed different understandings of the core concept and implemented it in different ways, including some which were not inquiry-related at all.

Finally, in this study teachers were very optimistic about the near future of science education in Rwanda. As pointed out earlier in this chapter, inquiry is a controversial issue in the field of science teaching and learning. Some researchers think inquiry is a positive

method of teaching science (e.g. Davis, 2001; Farenga, Joyce & Dowling, 2002; Llewellyn, 2005), while others think inquiry is a waste of time and does not broaden a student's perspective of science (e.g. Pierce, 2001).

Acknowledging the challenges associated with matching the reality of scientific inquiry in the classroom with the rhetoric in favour of its implementation (Dixon, 2012), I am in favour of the first view, and position myself alongside the teachers' views in this study. I am positive about the use of inquiry and the promising near future of science education in Rwanda. As a science teacher educator, I have expanded my knowledge and understanding about IBST both internationally and in the Rwandan context where the study was based. I cannot wait to go out to revisit and readjust my pre-service science teacher training. Furthermore, I feel more confident to provide my contribution to the in-service science teacher training, given the findings obtained from this study. This will assist in bringing inquiry into more classrooms, considering my belief that inquiry is the essence of good science education.

REFERENCES

- American Association for the Advancement of Science. (2008). AAAS will provide Science Curriculum Resources to Support Rwanda Education Plan. Retrieved 16 June, 2009 from: <http://www.aaas.org/news/releases/2008/1001rwanda.shtml>
- Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Hofstein, A., Lederman, N. G., Niaz, M., Treagust, D. & Tuan, H., (2004). Inquiry in Science Education: International Perspectives. *Science Education*, 88(3), 397- 419.
- Ackay, B. (2007). Effectiveness of professional development program on a teacher's learning to teach science as inquiry. *Asia-Pacific Forum of Science Learning and Teaching*, 8(2), 1-20.
- Anderson, R. D. (2002). Reforming science as inquiry: What research says about inquiry? *Journal of Science Teacher Education*, 13 (1), 1-12.
- Anderson, R. D. (2007). Inquiry as an Organizing Theme for Science Curricula. In S. K. Abell & N. G. Lenderman (Eds.), *Handbook of Research on Science Education*. (pp.807-830). New York: Routledge.
- Anthony, L. W. L. (2008). Teacher Concern about Curriculum Reform: The Case of Project Learning. *The Asia-Pacific Education Researcher*, 17 (1), 75-97.
- Applefield, J. M., Huber, R., & Moallen, M. (2001). Constructivism in Theory and Practice: Towards a Better Understanding. *The High School Journal*. Retrieved September 15, 2011 from: <http://www.jstor.org/stable/4148314>
- Argyris, C. (1996). *On Organisational Learning*. Oxford, UK: Blackwell Publishers.
- Ash, D., & Klein, C. (2000). Inquiry in the Informal Learning Environment. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 216-257). Washington, DC: AAAS.
- Atar, K. Y. (2007). *Investigating Inquiry Beliefs and Nature of Science (NOS) Conceptions of Science Teachers as Revealed though Online Learning*. Unpublished PhD Thesis, The Florida State University.
- Audet, R. H. (2005). Inquiry: A Continuum of Ideas, Issues and Practices. In R. H. Audet & L. K. Jordan (Eds.), *Integrating Inquiry across the Curriculum*. (pp. 5-15). New York: Corwin Press.
- Audet, R. H., & Jordan, L. K. (2003). *Standards in the Classroom: An Implementation guide for Teachers of Science and mathematics*. Thousand Oaks, CA: Corwin Press.

- Barman, C. R. (2002). Guest Editorial: How do you define inquiry? *Science & Children*, 39 (10), 8- 9.
- Barrow, L. H. (2006). A Brief History of Inquiry: From Dewey to Standards. *Journal of Science Teacher Education*, 17, 265- 278.
- Bassey, M. L. (1999). *Case study research in educational settings*. Philadelphia: Open University Press.
- Baviskar, S. N, Todd, XX, Hartle, R. T., & Whitney, T. (2009). Essential to characterize constructivist teaching: Derived from a review of literature and applied to five constructivist teaching method articles. *International Journal of Science Education*, 31(4), 541- 550.
- Bazeley, P. (2004). Issues in Mixing Qualitative and Quantitative Approaches to Research. In R. Buber, J. Gadner, & L. Richards (Eds.), *Applying qualitative methods to marketing management research*. (pp.141-156). UK: Palgrave Macmillan.
- Bless, C., & Higson-Smith, C. (2000). *Fundamentals of Social Research Methods*. Cape Town:Juta.
- Boden, M. A. (2010). Against Constructivism. *Journal of Constructivist Foundations*, 6(1), 84 - 89.
- Bodner, G. M. (1986). Constructivism: A Theory of Knowledge. *Journal of Chemical Education*, 63(10), 873-878.
- Bogdan, R. C., & Biklen S. K. (1992). *Qualitative Research for Education: An Introduction to Theory and Methods*. USA: Allyn and Bacon.
- Bonk, C. J., & Wisher, R.A. (2000). Applying collaborative and e-learning tools to military distance learning: A research framework. *Technical Report 1170*. United States Army Research Institute for the Behavioural and Social Sciences.
- Brooks, J. G., & Brooks, M. G. (1999). *In search of understanding: the case for constructivist classroom*. Alexandria, VA. Association for Supervision and Curriculum Development.
- Brown, J. D. (2001). *Using Surveys in Language Programs*. Cambridge, UK: Cambridge University Press.
- Brown, P. L., Abell, S. K., Demir, A., & Schmidt, F. J. (2006). College Science Teachers' views of classroom inquiry. *Science Education*, 90(5), 784- 802.
- Brown, S. L., & Melear, C. T. (2006). Investigation of Secondary Science Teachers' Beliefs and Practices after Authentic Inquiry-Based Experiences. *Journal of research in Science Teaching*, 43(9), 938-962.

- Buck, L. B., Bretz, S. L. & Towns, M. H. (2008). Characterizing the levels of inquiry in the undergraduate laboratory. *Journal of College Science teaching*, September/October, 52-58.
- Bybee, R. W. (2000). Teaching science as inquiry. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 20 - 46). Washington, DC: AAAS.
- Bybee, R. W. (2004). Scientific inquiry and science teaching. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and the nature of science*, (pp. 1-14). Boston: Kluwer.
- Capps, D. K., & Crawford, B. A. (2009). *Is science inquiry professional development effective? A critical review of empirical research*. A paper presented at NARST conference in Garden Grove, CA, April 17-20, 2009.
- Carin, A. A., Bass, J. E., & Constant, T. L. (2005). *Teaching Science as Inquiry*. Prentice Hall: ISBN: 0131181653
- Carl, A. E. (2009). *Teacher Empowerment through Curriculum Development: Theory into Practice* (3rd ed.). Cape Town: Juta and Company Ltd.
- Cavicchi, E., & Hughes-McDonnell, F. (2001). *Introducing investigation into the teaching and learning experiences of new teacher of science*. (ERIC Document Reproduction service No. ED470928)
- Chen, J. (2008). *Science Inquiry*. Retrieved June 25, 2011 from: <http://tccl.rit.albany.edu/knilt/index.php/Science-Inquiry>
- Cheng, Y. C. (1994). Effectiveness of curriculum change in school: An organisational perspective. *International Journal of Educational Management*, 8(3), 26-34.
- Cheung, D., Ng, D., & Hattie, J. (2000). The simplex structure of teachers' stages of concern about implementing a new curriculum. *Canadian and International Education*, 29(1), 109-122.
- Chin, R., & Benne, K. D. (1969). General Strategies for Affecting Changes in Human Systems. In W.G. Bennis, K.D. Benne, & R. Chin (Eds.), *The Planning of Change* (3rd ed.). (pp. 35 – 59). London: Holt, Rinehart and Winston.
- Chin, C., & Kayalvizhi, G. (2002). Posing problems for open investigations: What questions do pupils ask? *Research in Science & Technological Education*, 20 (2), 269-287.
- Choi, S., & Ramsey, J. (2009). Constructing elementary Teachers' beliefs, Attitudes, and Practical Knowledge through and Inquiry-based elementary Science Course. *School Science and Mathematics*, 109(6), 313-324.

- Christodoulou, N., Varelas, M. & Wenzel, S. (2009). Curricular Orientations, Experiences, and Actions: Graduate Students in Science and Mathematics Field Work in Urban High School Classrooms. *Journal of research in science education*, 46(1), 1-26.
- Cobern, W. W., Schuster, D., Adams, B., Applegate, B., Skjold, B., Undreiu, A., Loving, C. C. & Gobert, J. D. (2010). Experimental Comparison of Inquiry and Direct Instruction in Science. *Research in Science and Technological Education*, 28(1), 81-96.
- Cohen, L., Manion, L. & Morrisson, K. (2000). *Research Methods in Education*, (5thed.). London: Routledge Falmer.
- Cohen, L, Manion, L. & Morrisson, K. (2007). *Research Methods in Education*. (6thed). London: Routledge.
- Colburn, A. (2000). An inquiry primer. *Science Scope*, 23 (6), 42-44.
- Cole, M., & Wertsch, J. V. (2002). Beyond the individual-social antimony in discussions of Piaget and Vygotsky. The Prometheus Research Group. Retrieved on 25 June 2009 from: <http://www.des.emorg.edu/mfp/VygColeWer.pdf>
- Collier, C., Johnson, J., Nyberg, L. & Lockwood, V. (2012). *Learning Science Through Inquiry: Frequent Question Asked about Inquiry*. Retrieved on February 22, 2012 from: <http://www.learner.org/workshops/inquiry/resources/faq.html#3>
- Collin, K. M. T., Onwuegbuzie, A. J., & Sutton, I. L. (2006). A model incorporating the rationale and purpose for conducting mixed methods research in special education and beyond. *Learning Disabilities: A Contemporary Journal*, 4, 67- 100.
- Confrey, J. (1990). What constructivism implies for teaching. In R. B. Davis, C. A. Mather, & N. Noddings (Eds.), *Constructivist Views on the Teaching and Learning of Mathematics, Journal for Research in Mathematics Education Monograph*, 4 (pp. 107-122).
- Costenson, K., & Lawson, A. E. (1995). Why isn't inquiry used in more classrooms? *American Biology Teacher*, 48(3), 150-158.
- Crawford, B. A. (2000). Embracing the Essence of inquiry: New Roles for Science Teachers. *Journal of research in Science Teaching*, 37(9), 916-937.
- Cresdee, M. (2002). *Dealing with Curriculum Change: How teachers perceive recent curriculum changes and the strategies they employ to cope with such change*. Unpublished Master's Thesis, Murdoch University, Western Australia.
- Creswell, J. W. (2003). *Research design: Qualitative, Quantitative, and Mixed Methods Approaches*, (2nded.). London: Sage
- Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and Conducting Mixed Methods*. Thousand Oaks, CA: SAGE.

- Creswell, J. W. (2009). *Research design: Qualitative, Quantitative and Mixed Methods Approaches* (3rded.). London: Sage.
- Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and Conducting Mixed Methods Research*. (2nded.). Thousand Oaks, CA: SAGE.
- Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving Science Inquiry with Elementary Students of Diverse Backgrounds. *Journal of research in Science Teaching*, 42(3), 337-357.
- Davis, K. S. (2001). "Change Is Hard". What Science Teachers Are Telling Us About Reform and Teacher Learning of Innovative Practices. *Science Education*, 87(1), 3-30. Contract Grant No: R911182001
- Davis, K. S., & Irwin, C. (2001). *Building a bridge for females to equitable, inclusive, and participatory science activity*. (ERIC Document Reproduction Service No. ED454272).
- DeBoer, G. E. (1991). *A history of ideas in science education*. New York: Teachers College Press.
- Delport, C. S., & Roestenburg, W. J. H. (2005). Quantitative data-collection: questionnaire, checklists, structured observation and structured interview schedules. In De Vos, A. S., Strydom, H., Fouché, C. B. and Delport, C. S. L. (Eds.). *Research at grass roots*. (4thed.), (pp. 171-205), Pretoria: Van Schaik.
- Denscombe, M. (2003). *The Good Research Guide: For Small-scale Social Research Projects*. (2nded.). New York: Open University Press.
- Denzin, N. K., & Lincoln, Y. S. (1998). *Collecting and interpreting qualitative materials*. Thousand Oaks, CA: Sage
- De Souza Barros, S., & Elia, M. C. (1998). Physics Teachers' Attitudes: How do they affect the reality of the classroom and Models of change? In A. Tiberghien, E. L. Jossen & J. Barojos. (Eds.). *Connecting Research in Physics Education with Teacher Education*. (pp.86-91). ICPE.DOI: 10.1119/1.1367802. Retrieved 24 July, 2011 from: http://physics.ohio_state/~jossem/ICPE/BOOKS.html
- Deters, K. M. (2005). Student Opinions Regarding Inquiry-Based Labs. *Journal of Chemical Education*, 82(8), 1178-1180.
- Dixon, N. (2012). For teachers, there a rhetoric and a reality to scientific inquiry. *Perspectives on Education: Inquiry-based learning*. Retrieved June 30, 2012 from: http://www.wellcome.ac.uk/stellent/groups/corporatesite/cms_h_peda/documents/web_document/wtvm053965
- Dörnyei, Z. (2003). *Questionnaire in second language research: Construction, Administration and Processing*. USA: Erlbaum Associates.

- Driver, R. (1989). Changing conceptions. In P. Adey (Ed.), *Adolescent development and school science*. (pp. 79-99). London: Falmer Press.
- Duit, R. (2001). *The constructivist view in science education – What is has to offer and what should not be expected from it*. Retrieved February 12, 2009, from <http://www.if.ufrgs.br/public/ensino/N1/3artigo.htm>
- Earnest, J. (2003). *Science Education Reform in a Post-colonial Developing Country in the Aftermath of a Crisis: The Case of Rwanda*. Unpublished PhD thesis, Curtin University of Technology, Australia.
- Earnest, J., & Treagust, D. (2001). *Voice from the Classroom: Teachers' and Students' Perceptions and Experiences on Science Education Reform in a Transitional Society*. Paper presented at the International Education Research Conference of the Australian Association for Research in Education, held in Freemantle, Australia, 2- 6 December, 2001.
- Earnest, J., & Treagust, D. (2007). *Educational Reform in Countries under Transition*. Rotterdam: Sense Publishers.
- Eastwell, P. (2007). Your Questions Answered. *The Science Education Review*, 6(3), 94-113.
- Ediger, M. (2001). Assessing: Inquiry Learning in Science. Retrieved 20 October, 2011 from: <http://eric.ed.gov/PDFS/ED454274.pdf>
- Education Broadcasting Corporation (2004). Constructivism as a Paradigm for Teaching and Learning. Retrieved 12 February, 2009, from: <http://www.triirteen.org/endonline/concept2class/constructivism.index.html>
- Eick, C. J., & Reed, C. J. (2002). What Makes an Inquiry-Oriented Science Teacher? The Influence of Learning Histories on Student Teacher Role Identity and Practice. *Science Education*, 83(3), 401-416.
- Ekiz, D. (2004). Teacher professionalism and curriculum change: Primary school teachers' views of the new science curriculum. *Kastamonu Education Journal*, 12 (2), 339-350.
- Eltinge, E., & Roberts, C. (1993). Linguistic content analysis: A method to measure science inquiry in textbooks. *Journal of Research in Science Teaching*, 30, 65- 83.
- Enyedy, N., & Goldberg, J. (2004). Inquiry in interaction: how local adaptations of curricula shape classroom communities. *Journal of research in science Teaching*, 41, 905-935.
- Ernest, P. (1995). The one in the many. In L. Steffe & J. Gale (Eds.). *Constructivism in Education*. (pp. 459-486), New Jersey: Lawrence Erlbaum Associate, Inc.
- Farenga, S. J., Joyce, B. A., & Dowling, T. W. (2002). Rocketing into adaptive inquiry.

Science Scope, 25(4), 34-39.

Fay, M. E., & Bretz, S. L. (2008). Structuring the level of inquiry in your classroom: A rubric helps teachers compare experiments and plan inquiry trajectories. *The Science Teacher*, 75(5), 38-42.

Fosnot, C. (1996). Constructivism: A Psychological theory. In C. Fosnot (Ed.). *Constructivism: Theory, perspectives, and practice* (pp. 8- 33). New York: Teachers College Press.

Fraenkel, J. R., & Wallen, N. E. (2007). *How to design and evaluate research in education*, (6th ed.). New York: McGrawHill.

Fritcher, L. (2008). *Constructivism*. Retrieved 25 June, 2011 from:
<http://phobias.about.com/od/glossary/g/constructivdef.htm>

Fullan, M. G. (1991). *The new meaning of educational change*. New York: Teachers College Press.

Fullan, M. G. (1993). Innovation, reform, and restructuring strategies. In G. Cawetti (Ed.). *Challenges and Achievements of American Education*. Alexandria, VA: ESCD.

Fullan, M. G. (2001). *The new meaning of educational change* (3rd ed.). New York: Columbia University: Teacher College Press.

Fullan, M. G. (2007). *The new meaning of educational change* (4th ed.). New York : Columbia University: Teacher College Press.

Gado, I. (2005). Determinant of K-2 School Teachers' Orientation towards Inquiry-Based Science Activities: A Mixed Method Study. *International Journal Science and Mathematics Education*, 3, 511-539.

Gallagher , J. J., & Tobin, K. (1991). Reporting interpretive research. In J. J. Gallagher (Ed.). *Interpretive Research in Science Education. NARST Monograph No. 4*, (pp. 85-95). Kansas State University, Manhattan: NARST.

Gash, H. (2009). What You Always Wanted to Know about Constructivist Education. *Journal of Constructivist Foundations*, 5(1), 64-65.

Gibson, H. L., & Chase, C. (2002). Longitudinal Impact of an Inquiry-Based science Program on Middle School Students' Attitudes Toward Science. *Science Education*, 86 (5), 693-705.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report*, 8(2), 597-607. Retrieved February 25, 2009 from:
<http://www.nova.edu/ssss/QR/QR8-4/golafshani.pdf>

Good, R. G., Wandersee, J. H., & Julien, J. (1993). Cautionary notes of the appeal of the new

- “ism” (constructivism) in science education. In K. Tobin (Ed.). *The practice of constructivism in science education*, (pp. 71-87). Thousand Oaks, CA: Sage.
- Gödek, Y. (2009). The development of science education in developing countries. *G.Ü. Kirşehir Eğitim Fakültesi Dergisi*, 5(1), 1-9.
- Gravetter, F. J., & Forzano, L. B. (2003). *Research methods of behavioural sciences*. Belmont: Wadsworth Thomson Learning.
- Greff, M. (2005). Information collection: Interviewing. In A. S. de Vos, H. Strydom, C. B. Fouché & C. S. L. Delport. (Eds.). *Research at grass roots: For the social sciences and human service professions* (3rd ed.), (pp. 286- 313). Pretoria: Van Schaik.
- Grix, J. (2002). Introducing Students to the Generic Terminology of Social Research. *Politics*, 22(3), 175-186.
- Haefner, L. A., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teacher’s developing understanding of scientific inquiry and science teaching and learning. *International Journal of Science Education*, 26(13), 1653-1674.
- Hammerman, M. (2000). Varieties of social research: A typology. *The International Journal of Social Research Methodology: Theory and Practice*. 3(2), 221 -231.
- Hammerman, E. (2006). *8 Essentials of Inquiry-Based Science, K-8*. California: Thousand Oaks, SAGE.
- Haney, J. J., Lumpe, A. T., & Czerniak, C. M. (2003). Constructivist Beliefs about the Science Learning Environment: Perspectives from Teachers, Administrators, Parents, Community Members, and Students. *School Science and Mathematics*. Retrieved 29 March, 2009 from: http://findarticles.com/p/articles/mi_qa3667/is_200312/ai_n316314
- Harlen, W., & Allende, J. E. (2006). *Report of the Working Group on International Collaboration in the Evaluation of IBSE programs*. University of Santiago, Chile.
- Harste, J. (1993). Inquiry-based Instruction. *Primary Voices K-6*. 1, 2-5.
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99-107.
- Heifetz, R. A. (1994). *Leadership without easy answers*. Cambridge: Belknap Press.
- Henning, E., van Rensburg, W., & Smit, B. (2004). *Finding your way in qualitative research*. Pretoria: Van Schaik.
- Hesse-Biber, S., & Leavy, P. (2006). *The practice of qualitative research*. Thousand Oaks: Sage

- Hinrichsen, J., & Jarrett, D. (1999). *Science Inquiry for Classroom: A literature review*. Portland: NWREL.
- Honebein, C. (1996). Seven Goals for the Design of Constructivist learning. Retrieved 18 August, 2010 from: <http://www.ingilish.com/constructivist-model.htm>
- Hooijberg, R., & Dodge, G. (1997). Leadership Complexity and Development of the Learnerplex Model. *Journal of Management*, 23(3), 375 – 408.
- Horner, S. (2012). Scientific inquiry: mere pedagogy or real science? And who decides? *Perspectives on Education: Inquiry-based learning*. Retrieved 30 June, 2012 from: http://www.wellcome.ac.uk/stellent/groups/corporatesite/cms_h_peda/documents/web_document/wtvm053965
- Inter Academic Panel (IAP). (2010). *Taking Inquiry-Based Science Education (IBSE) into Secondary School*. International Conference held at University of York, York, UK, 27-29 October 2010.
- Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using Mixed-Methods Sequential Explanatory Design: from Theory to practice. Online: Retrieved 14 July, 2011 from: <http://fmj.sagepub.com/content/18/1/3.refs.html>
- Ivankova, N. V., Creswell, J. W., & Plano Clark, V. L. (2007). Foundations and approaches to mixed methods research. In K. Maree (Ed.). *First steps in research*, (pp. 253- 280). Pretoria: Van Schaik.
- Iyamuremye, P. C. (1966). *Colloque sur la Politique Scientifique et Administrative de la Recherche Scientifique en Afrique*. Yaoundé.
- Jamieson, S. (2004). Likert scales; how to (ab)use them. *Medical Education*, 38, 1212-1218.
- Jenkins, E. (2000). 'Science for all': Time for a paradigm shift? In R. Millar, J., Leach & J. Osborne (Eds.), *Improving science education: The contribution of research*. (pp. 207-226), Buckingham, UK: Open University Press.
- Jonassen, H. D. (1991). Objectivism versus Constructivism: Do we need a new Philosophical Paradigm? *Educational Technology Research & Development*, 39(3), 5-14.
- Jonassen, H. D. (1994). *Thinking Technology: Toward a Constructivist Design Model*. *Educational Technology*, 34(4), 34-37. Retrieved 24 May, 2010 from: <http://ouray.cudenver.edu/~slanfor/constdm.txt>
- Johnson, C. C. (2006). Effective Professional Development and Change in Practice: Barriers Science Teachers Encounter and Implications for reform. *School Science and Mathematics*, 106 (3), 150-161.
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research

- Paradigm Whose Time has come. *Educational Researcher*, 33(7), 14-26.
- Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed methods Research*, 1(2), 112- 133.
- Jordan, L. K. (2005). Science Inquiry: Is There any Other Way? In R.H. Audet, & L. K. Jordan (Eds.). *Integrating Inquiry across the Curriculum*. (pp. 43 – 630. Thousand Oaks, CA: Crown Press.
- Kane, E., & O'Reilly-de Brun, M. (2001). *Doing your own research*. London : Marion Boyars.
- Karen, L. (2002). *Technology and Educational Innovation: A Case Study of the Virtual Campus of the University of Pretoria*. Unpublished PhD thesis, University of Pretoria.
- Kawulich, B. B. (2005). Participant Observation as a Data Collection Method. *Forum: Qualitative Social Research*, 6(2), Art 43. Retrieved July 5, 2012 fro: <http://www.qualitative-research.net/index.php/fqs/article/view/466/997>
- Kennedy, C. (1996). Teachers' Roles in Curriculum Reform. *ELTED*, 2(1), 77- 89.
- Kerlin, S. C., McDonald, S. P. & Kelly, G. J. (2009). Mapping a Science Inquiry Unit. *Journal of Classroom Interaction*, 44(2), 4-13.
- Keys, C. W., & Bryan, L. A. (2001).Co-Constructing Inquiry-Based Science with Teachers: Essential Research for Lasting Reform. *Journal of Research in Science Teaching*, 38(6): 631-645.
- Khan, M. A. (2009). Teaching of heat and temperature by hypothetical inquiry approach: A sample of inquiry teaching. *JPTEO*, 5(2), 43-64.
- KIE. (2009). Kigali Institute of Education: Academics. Retrieved 15 October, 2011 from: <http://www.kie.ac.rw/contents/see/1/2/43>
- Kleine, K., Brown, B., Harte, B., Hilson, A., Malone, D., Moller, K., Niblett, A., Toole, M. & Walker, B. (2002). Examining Inquiry. *Principal Leadership (Middle School Ed.)*, 3(3), 36-39.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance during Instruction does not work: An Analysis of the Failure of Constructivist, Discovery, Problem-based, Experimental, and Inquiry-based Teaching. *Educational Psychologist*, 41(2), 75-86.
- Krajcik, J., Blumenfeld, P., Marx, R., & Soloway, E. (2000). Instructional, Curricular, and Technological Support for Inquiry in Science Classroom. In J. Minstrell & E.H. van Zee (Eds.), *Inquiring in Inquiry Learning and Teaching in Science*. (pp. 283-315). Washington, D.C: AAAS.

- Kubiek, J. (2005). Inquiry-Based Learning, the Nature of Science, and Computer Technology: New Possibilities in Science Education. *Canadian Journal of Learning and Technology*. Retrieved 10 July, 2011 from; <http://www.cjlt.ca/index.php/article/view/149/142>
- Layman, J. W. (1996). *Inquiry and Learning: Realizing Science Standards in the Classroom*. College Board, USA.
- Lee, O., Hard, J. E., Cuevas, P., & Enders, C. (2004). Professional development in inquiry based science for elementary teachers of diverse students groups. *Journal of Research in Science Teaching*, 40(10), 1021-1043.
- Llewellyn, D. (2005). *Teaching High school Science Through Inquiry: A case study approach*. Thousand Oaks, Ca: Corwin Press.
- Leonard, W. H., & Penick, J. E. (2000). The Limits of Learning. A Standards-based Activity for Biology Classroom. *The American Biology Teacher*, 62(5), 359-361.
- Leonard, W. H., & Penick, J. E. (2009). Is the Inquiry Real? Working definition of inquiry in the science classroom. *The Science Teacher*, 76(5), 24-27.
- Levin, B. & Riffle, J. A. (2000). Changing Schools in a Changing World. In N. Bascia & A. Hargreaves (Eds.), *The Sharp Edge of Educational Change: Teaching, Leading, and Realities of Reform*. (pp. 178-194). London: Routledge- Falmer.
- Lewin, K. M. (1992). *Science Education in Developing Countries: Issues and Perspectives for Planners*. Paris: UNESCO.
- Lewthwaite, B. (2006). "I want to enable teachers in their change": Exploring the role of a superintendent on science curriculum delivery. *Canadian Journal of Educational Administration and Policy*, 52, 1-24.
- Linn, M. C. (2000). Designing the Knowledge Integration Environment. *International Journal of Science Education*, 22(8), 781-796.
- Linn, M. C., Clarck, D., & Slotta, J. D. (2003). Wise Design for Knowledge Integration. *Science Education*, 87, 517-538.
- Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (2003). *Designing Professional development for Teachers of Science and Mathematics*, (2nd ed), Thousand Oaks: Corwin Press.
- Maree, K., & Pietersen, J. (2007). Sampling. In K. Maree (Ed.). *First Steps in Research*. (pp. 172-182), Pretoria: Van Schaik Publishher.
- Marsha, L. M. (2000). *Teaching and learning by inquiry*. The American Psychological Society [APS]: Bethesda, M.D.

- Martin, D. J. (2001). *Elementary Science Methods: A Constructivist Approach*, (3rd ed.). Belmont: Thomson Wadsworth.
- Martin, D. J. (2006). *Elementary Science Methods: A Constructivist Approach*, (5th ed.). Wadsworth: Cengage Learning.
- Matthews, M. R. (2002). Constructivism and Science Education: A Further Appraisal. *Journal of Science Education and Technology*, 11(2):121-134.
- McBridge, J. W., Bhatti, M. I., Hannan, M. A., & Feinberg, M. (2004). Using an inquiry approach to teach science to secondary school science teachers. *Physics Education*, 39(5), 434- 439.
- McBuney, D. H. (2001). *Research methods*. London: Wadsworth Thomson Learning.
- Melear, C. T. (2000). *Immersion as Facilitated Engagement in Scientific Practice with peers and Experts as Preparation for Secondary Science Teacher*. Paper presented at the annual meeting of Southeastern Association for the Education of Teachers in Science. Auburn University.
- McMillan, J. H. & Schumacker, S. (2010). *Research in Education: Evidence-Based Inquiry*, (7th ed.). Upper Saddle River: Pearson
- Merrill, M. D. (1991). Constructivism and Instructional Design. *Educational Technology*. May, 45-53.
- Mertler, C. A., & Charles, C. M. (2008). *Introduction to educational research* (6th ed.). Boston, MA: Pearson Education.
- Mertens, D. M. (2010). *Research and Evaluation in Education and Psychology: Integrating Diversity with Quantitative, Qualitative, and Mixed Methods* (3rd ed). London: SAGE.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage
- MINEDUC. (1998a). *Education policy statement*. Kigali: MINEDUC.
- MINEDUC. (1998b). *Plan of action for education in Rwanda (1998-2000): Recovery and development*. MINEDUC with support of UNDP and UNESCO. Kigali: MINEDUC.
- MINEDUC. (2003). *Education Strategic Plan (2003-2008)*. Kigali: MINEDUC
- MINEDUC. (2007a). *The Ministry of Education Strategic Plan*. Kigali: MINEDUC
- MINEDUC. (2007b). *Ordinary Level Science Curriculum (Biology, Chemistry, Physics)*. Kigali: MINEDUC.

- MINEDUC. (2007c). *Teacher Development and Management Policy*. Kigali: MINEDUC.
- MINEDUC. (2008a). *Education Sector Strategic Plan 2008-2012*. Kigali: MINEDUC.
- MINEDUC. (2008b). *Statistics of the Ministry of Education 2007*. Kigali: MINEDUC
- MINEDUC. (2008c). *A Study on the Implementation of the new O'level Science Curriculum and the Impact of the Related Science Teachers' Training on the Improvement of Science Teaching and Learning*. Unpublished Study Report. Kigali: NCDC-BTC/MINEDUC.
- MINEDUC. (2010). *Education Sector Strategic Plan (2010-2015)*. Kigali: MINEDUC.
- Minstrell, J., & van Zee, E. (2000). *Inquiring into Inquiry Learning and Teaching in Science* (Eds.). Washington, DC: AAAS.
- Monette, D. R., Sullivan, T. J. & Dejong, C. R. (2008). *Applied research: A tool for the human services* (7th ed.).USA: Brooks/Cole.
- Moore, K. C. (2004). Constructivism and Metacognition. Tier 1 Performance Solutions. Retrieved on 25 June, 2010 from:
www.tierperformance.com/Article/Constructivism.pdf
- Murphy, E. (1997). *Constructivism: From Philosophy to Practice*. Retrieved 11 February, 2009 from: <http://www.uccs.mun.ca/~emurphy/stemmnet/de.html>
- Nieuwenhuis, J. (2007). Qualitative research designs and data gathering. In K. Maree (Ed.). *First steps in research*, (pp. 69-97). Pretoria: Van Schaik.
- NRC. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.
- NRC. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.
- Oates, K. K. (2002). Inquiry Science: Case Study in Antibiotic Prospecting. *American Biology Teacher*, 4(3), 184-187.
- Obura, A. (2003). *Never Again: Educational reconstruction in Rwanda*. International Institute for Educational Planning. Retrieved 12 November, 2011 from:
<http://www.unesco.org/iiep>
- Onwuegbuzie, A. J., & Teddlie, C. (2003). A framework for analysis data in mixed methods research. In A. Tashakkori & C. Teddlie, (Eds.), *Handbook of mixed methods in social and behavioral research*, (pp. 351-384). Thousand Oaks: Sage
- Onwuegbuzie, A. J., & Johnson, B. (2006). The validity issues in mixed research. *Research in Schools*, 13(1), 48- 63.

- Oppenheim, A. N. (1992). *Questionnaire Design, Interview and Attitude measurement*. Michigan: Printers Publishers. ISBN: 1855670437.
- Ottevanger, W., Van den Akker, J. & de Feiter, L. (2007). *Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa: Pattern and Promising Practices*. Washington, D.C: World Bank Working Paper, No 101.
- Pallant, J. (2007). *SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows*, (3rd ed.) New York: McGraw Hill.
- Penner, D. E. (2001). Cognition, Computer, and Synthetic Science: Building Knowledge and Meaning through Modelling. In W. G. Secada (Ed.). *Review of Research in Education 2000-2001*. (pp. 1-35). Washington, DC: AERA.
- Pierce, W. (2001). Inquiry made easy. *Science and Children*, 38(8), 39-41. Record detail: EJ628554.
- Pillay, A. S. (2005). *Responses of Science Teachers Educators to the Curriculum Change Process in South Africa*. Unpublished PhD Thesis, University of KwaZulu-Natal.
- Platton, M. Q. (2002). *Qualitative research and evaluation methods*, (3rd ed.). Thousand Oaks: Sage.
- Powell, K. C., & Kalina, C. J. (2009). Cognitive and Social Constructivism: Developing tools for an effective classroom. *Education*, 130(2), 241-250
- Powers, G. T., Meenaghan, T. M. & Toomey, B. G. (1985). *Practice Focused Research Integrating Human Service Practice and Research*. New Jersey: Prentice Hall.
- Pulkkinen, J., & Ruotsalainen, M. (1997). Telematics for teacher training: The lego/logo construction kit goes on the web. *Book of Abstracts, On-line Educa Berlin International Conference on Technology Supported Learning*, Oct 29-31: 87-91
- Punch, K. F. (2009). *Introduction to Research Methods in Education*. London: SAGE.
- Punuel, W. R., Fishman, B. J., Yamaguchi, R. & Gallagher, L. P. (2007). What Makes Professional development Effective: Strategies That Foster Curriculum Implementation. *American Educational Research Journal*, 44 (4): 921-958.
- Quinn, R. E., Spreitzer, G. M. & Brown, M. V. (2000). Changing Others Through Changing Ourselves: The Transformation of Human Systems. *Journal of Management Inquiry*, 9(2), 147 – 164.
- Richardson, V. (2003). Constructivist Pedagogy. *Teacher College Record*, 105(9), 1623-1640.
- Ridden, P. J. (1991). *Managing Change in Schools: A Step by Step Guide to Implementing Change*. Sydney: Ashton Scholastic.

- Riegler, A. (2005). Editorial: The Constructivist Challenge. *Constructivist Foundation*, 1(1), 1-8.
- Rogan, J. M., & Grayson, D. J. (2003). Towards a Theory of Curriculum Implementation with Particular Reference to Science Education in Developing Countries. *International Journal of Science Education*, 25(10), 1171-1204.
- Rwanda Education Gateway (2010). *From Traditional School to Modern School*. Retrieved 16 February, 2011 from:
http://www.rwandagateway.org/education/article.php3?id_article=85
- Rushton, G. T., & Lotter, C. (2011). Chemistry teachers' Emerging Expertises in Inquiry Teaching: The Effect of a Professional development Model on Beliefs and Practice. *Journal of science Education*, 22: 23-52.
- Ryder, M. (2005). *Instructional Design Model*. Retrieved 20 August, 2012 from:
http://canrbon.cudenver.edu/~mryder/itc_data/idmodels.html
- Sahlberg, P. (2003). Education change. In J. Guthrie (Ed.). *Encyclopaedia of Education*, (2nd ed.). New York: Macmillan. Retrieved 24 November, 2010 from:
<http://www.pasisahlberg.com/index.php?id=54>
- Sahlberg, P. (2006). Curriculum change: In search of better implementation. In P. Sahlberg (Ed.). *Curriculum reform and implementation in the 21st century: policies, perspectives and implementation*. Proceeding of the International conference on curriculum reform and implementation, Ankara, Turkey, Ministry of Education, pp. 18-30.
- Seigel, S. (2004). *Constructivism as a Paradigm for Teaching and Learning*. Retrieved on May 30, 2011 from:
<http://www.thirteen.org/edonline/concept2class/constructivism/index.html>
- Sergiovanni, T. M. (1998). Organization market and community as strategies for change: What works best for deep changes. In A. Hargreaves, A. Lieberman, M. Fullan, & D. Hopkins (Eds.). *International Handbook of Educational Change*. (pp. 576- 595), Dordrecht: Kluwer.
- Settlage, J. (2003, April). *Inquiry's allure and illusion: Why it remains just beyond our reach*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, P. A.
- Sinclair, M. (2001). "Education in emergencies." In J. Crisp, C. Talbot & D. Cipollone, (Eds.). *Learning for the Future: Refugee Education in developing Countries*, (pp. 1-83). Geneva: UNHCR. Retrieved on June 21, 2010 from:
<http://www.unesco/iep/PDF/Fund73.pdf>
- Smithenry, D. W. (2010). Integrating Guided Inquiry into a Traditional Chemistry Curricular

- Framework. *International Journal of Science Education*, 32(13), 1689-1714.
- Songer, N. B., Lee, H. S., & McDonald, S. (2003). Research towards an Expanded Understanding of Inquiry Science Beyond one Idealized Standard. *Science Education*, 87, 490-516.
- Strydom, H. (2005a). Sampling and Sampling Methods. In A.S. de Vos, H. Strydom, C. B. Fouché & C. S. L. Delport. (Eds.). *Research at Grass Roots: For the social sciences and human service professions* (3rd ed.), (pp. 192- 204). Pretoria: Van Schaik.
- Strydom, H. (2005b). The pilot study. In A. S. de Vos, H. Strydom, C. B. Fouché and C. S. L. Delport, (Eds.). *Research at Grass Roots: For the Social Sciences and Human Service Professions* (3rd ed.), (pp. 205- 216). Pretoria: Van Schaik.
- Supovitz J. A. & Turner, H. M. (2000). The Effects of Professional Development on science teaching Practices and Classroom culture. *Journal of research in Science Teaching*, 37 (9): 963-980.
- Sutman, F. X., Schmuckler, J. S., & Woodfield, J. D. (2008). *The science quest: Using Inquiry/Discovery to Enhance Student Learning*. USA: Jossy-Bass.
- Taber, K. S. (2009). *Progressing Science Education: Constructing the Scientific Research Programme into the Contingent Nature of Learning Science*. Dordrecht: Springer.
- Tashakkori, A., & Teddlie, C. (2003). Major Issues and Controversies in the use of Mixed Methods in the Social and Behavioural Sciences. In A. Tashakkori & C. Teddlie (Eds.). *Handbook of Mixed Methods in Social and Behavioural Research*, (pp. 3-50). Thousand Oaks: Sage.
- Taylor, J. R. (1993). *Rethinking the Theory of Organizational Communication. How to Read an Organization*. Norwood, N.J: Ablex
- The New Dictionary of Social Work* (1995). (Revised and comprehensive edition). Terminology Committee of Social Work. Pretoria: State Printers. ISBN: 0062116980
- Tobias, S., & Duffy, T. (2009). The Success or Failure of Construction Instruction: An Introduction. In S. Tobias & T. Duffy (Eds.). *Constructivist Instruction: Success or Failure*. (pp. 3-10). New York: Routledge.
- Van den Akker, J. (2003). Curriculum Perspectives: An Introduction. In J. Van den Akker, W. Kuiper & U. Hameyer (Eds.). *Curriculum Landscape and Trends*, (pp. 1-10). Dordrecht: Kluwer Academic Publishers.
- Volkman, M. J., & Abell, S. K. (2003). Rethinking Laboratories. Tools for Converting Cookbooks Labs into Inquiry. *The Science Teacher*, 70 (6), 38-41.
- Von Glaserfeld, E. (1995). A Constructivist Approach to Teaching. In L. Steffe & J. Gales,

- (Eds.). *Constructivism in education*. (pp. 3-16). New Jersey: Lawrence Erlbaum Associates.
- Walker, M. D. (2007). *Teaching Inquiry-based Science: A Guide for Middle and High School Teachers*. UK: Luku-Com.
- Webster's Third International Dictionary*. (1986). Springfield, MA: Merriam-Webster.
- Wee, B., Shepardon, D., Fast, J., & Harbor, J., (2007). Teaching and Learning about Inquiry: Insights and Challenge in Professional Development. *Journal of Science Teacher Education*, 18, 63-89.
- Welch, W., Klopfer, L., Aikenhead, G., & Robinson, I. (1981). The Role of Inquiry in Science Education: Analysis and Recommendations. *Science Education*, 65, 35-50.
- Welleman, P. F. & Wilkinson, L. (1993). Nominal, Ordinal, Interval and Ratio Typology are misleading. *The American Statistician*, 47(1), 65-72.
- Wenning, C. J. (2005a). Levels of Inquiry: Hierarchies of Pedagogical Practices and Inquiry Processes. *JPTEO*, 2(3), 3-11.
- Wenning, C. J. (2005b). Implementing Inquiry-based Instruction in the Science Classroom: Anew model for solving the improvement-of-practice problem. *JPTEO*, 2(4), 9-15.
- Wenning, C. J. (2010). Levels of Inquiry: Using inquiry spectrum learning sequence to teach science. *JPTEO*, 3(3), 11-20.
- Wenning, C. J. (2011). The Levels of Inquiry Model of Science Teaching. *JPTEO*, 6(2), 9-20.
- Wheeler, G. F. (2000). The Three Faces of Inquiry. In J. Minstrell, & E.H. van Zee (Eds.). *Inquiring into Inquiry Learning and Teaching in Science*. Washington, D.C: National Academy Press.
- Wideen, M. & Pye, I. (1994). *The Struggle for Change: The Story of one School*. London: The Falmer Press
- Wilfred, A. F. (s.d). *Inquiry Based Approaches to Science Education: Theory and Practice*. Retrieved on February 8, 2009 from:
<http://www.brynmawr.edu/biology/franklin/InquiryBasedScience.html>
- Willoughby, J. (2005). *Using inquiry in Science Instruction*. Retrieved 25 February, 2009 from: http://www.glencoe.com/sec/teachingtoday/subject/using_inquiry_sci.phtml
- Wilson, B. G., & Cole, P. (1991). Cognitive Dissonance as an Instructional Variable. *Ohio Media Spectrum*, 43(4), 11-21.
- Windschitl, M. (2000). *Pre-service Science Teachers and Independent Inquiry Experience*.

(ERIC Document Reproduction Service No. ED441703).

Windschitl, M. (2004). Caught in the cycle of reproducing folk theories of inquiry: How pre-service teachers continue the discourse and practices of an atheoretical scientific method. *Journal of research in Science Teaching*, 41(5), 481-512.

Yager, R. E. (1991). The Constructivist Learning Model: Toward Real Reform in Science Education. *Science Teacher*, 58(6), 52-57.

Yager, R. E. (1993). The need for reform in science teacher education. *Journal of Science Teacher Education*, 4 (4), 144-148.

Yin, H., & Li, Z. (2007). On teachers' change in Curriculum Reform. *Educational Research*, 28(3), 23- 29.

Yin, R. K. (2006). Mixed Methods Research: Are the methods genuinely integrated or merely parallel? *Research in the School*, 13 (1), 41- 47.

APPENDICES

APPENDIX A: QUESTIONNAIRE

QUESTIONNAIRE FOR SCIENCE TEACHERS

Introduction

Dear science teacher,

As you know, you are implementing a new science curriculum that focuses on inquiry and such change has numerous implications both on teaching and learning. As part of my PhD studies, I am currently conducting research on the introduction of inquiry science teaching at lower secondary school focusing on the science teachers' response to the introduction of this teaching approach into the science curriculum.

For this purpose, I would really appreciate if you could spend some time to assist me by completing this questionnaire. The information you provide will be used solely for the academic end. You will not be identified by name as well as your school in any report and all information will be treated confidentially.

Please sign to indicate that you freely agree to participate and give your informed consent. You may withdraw your consent at any time if you wish to do so. However, even if you decide to withdraw, please return the questionnaire.

Many thanks for your co-operation.

PS: If you would like to query anything about this study, do not hesitate to contact me or the project supervisor at the following addresses:

The Student:
Leon Mugabo
(+27) 0788522916
(+250) 0736128308
e-mail: mugabol2000@yahoo.com

The Supervisor:
Paul Hobden
(+27) 0825474031
e-mail: hobden@ukzn.ac.za

Informed consent

I, (Name, but optional) give, by my own, permission to use for academic purpose the data from this questionnaire. I am aware that I am free to withdraw my consent at a later stage if I so wish.

Signed:..... Date:

SECTION 1: BIBLIOGRAPHICAL DATA / *DONNEES BIBLIOGRAPHIQUES*

1.1. The teacher (Please complete the following table and where relevant tick in the appropriate box)

L'enseignant (Veuillez compléter le tableau suivant en mettant ✓ dans la case qui convient là où c'est approprié).

1. Names (Optional)/ <i>Noms (Facultatif)</i> <i>Identities will not be disclosed / L'identité sera tenue secrète</i>		
2. Number of years of teaching science (e.g. 6 years) <i>Nombre d'années d'enseignement de science (ex. 6 ans)</i>		
3. Your qualification <i>Votre qualification</i>	A2 A1 A0 Other (specify)..... A2 A1 A0 Autre (spécifier).....	
4. Your specialization (e.g. BCE, PCE, MPE,) <i>Votre spécialisation (ex. BCE, PCE, MPE,)</i>		
5. Subject and class taught this year (e.g. Physics, 2 nd year) <i>If possible attach your full time table using the template provided at the end of this questionnaire.</i>		

1.2. The School.(Please complete the following table and where relevant tick in the appropriate box).

L'Ecole.(Veuillez compléter le tableau suivant en mettant ✓ dans la case qui convient là où c'est requis).

1. Name of the School / <i>Nom de l'école</i>		
2. Statute * (e.g. Pu, Pr, Co) <i>Statut * (ex. Pu, Pr, Co)</i>	Pu Pr Co Pu Pr Co	
3. Streams / <i>Sections</i>	“Tronc commun” (TC) or O’level only <i>Tronc commun seulement</i>	
	TC with science streams only <i>TC avec section scientifiques seulement</i>	
	TC with other streams than science <i>TC avec autres sections que scientifiques</i>	
	TC with other streams including science <i>TC avec autres sections dont scientifiques</i>	
4. Number of learners in your classes/ <i>Nombres d'élèves dans vos classes</i> (eg. 2 nd year B : 45/ ex. 2 ^{ème} B : 45)		
5. Number of other science teachers in TC/ <i>Nombre d'autres enseignants de science au TC</i>		
6. School location / <i>Situation de l'école</i>	Urban Rural <i>Urbain Rural</i>	
	Province:	
	District:	

* : Pu = Public/ *Publique*, Pr = Private/ *Privée*, Co = State granted by convention/ *Conventionnée ou libre subsidiée*

1.3. School science resources / Ressources de science à l'école

a) Where do you teach the majority of your TC sciences lessons?/Où enseignez-vous la plupart de vos leçons de sciences au TC?

- i. in a classroom / dans une salle de classe
- ii. in a laboratory/ au laboratoire
- iii. in a lecture room/ dans une salle d'étude
- iv. Other/ autre (specify/ spécifier).....

b) What lab does the school have for the teaching of TC science? Quel labo l'école dispose-t-elle pour enseigner les sciences au TC?

Biology lab/ Labo de Biologie :	Yes/ Oui	No/ Non
Chemistry lab / Labo de Chimie:	Yes/ Oui	No/ Non
Physics lab/ Labo de Physique:	Yes/ Oui	No/ Non
General purpose lab/ Labo d'usage multiple	Yes/ Oui	No/ Non
Other setting (specify)/ Autre disposition (spécifier)		

.....

c) How are they equipped? Comment sont-ils équipés ?

Rank from 1 to 5 where 5 = Fully equipped for all experiments at TC level and 1 = not equipped at all.

Attribuez une note de 1 à 5 où 5 = Totalement équipés pour toutes les expériences du niveau TC et 1= non équipés du tout.

Rank of the state of equipment/ Rang de l'état d'équipement	5	4	3	2	1
1. Biology lab/ Labo de biologie					
2. Chemistry lab/ Labo de chimie					
3. Physics lab/ Labo de physique					

d) If there is no lab how do you deal with lessons that require lab practical work?

S'il n'y a pas de labo, comment procédez-vous pour des leçons qui nécessitent des activités pratiques de labo?

.....

.....

.....

.....

SECTION 2: SCIENCE CURRICULUM / CURRICULUM DE SCIENCE

2.1. Based on your current experience, indicate whether you agree or disagree with the following statements about the new science curriculum.

Sur base de votre actuelle expérience, indiquer si vous êtes d'accord or non avec les propositions suivantes en rapport avec le nouveau curriculum des sciences.

Statements/ Propositions	Strongly agree/ <i>Tout à fait d'accord</i>	Agree/ <i>D'accord</i>	No opinion/ <i>Sans opinion</i>	Disagree/ <i>Désaccord</i>	Strongly disagree/ <i>Tout à fait désaccord</i>
1. There was a need of changing the old (prior to 2007) science curriculum / <i>Il était nécessaire que l'ancien (d'avant 2007) curriculum change</i>					
2. I was involved in the change process / <i>J'étais impliqué dans le processus de changement</i>					
3. I am fully confident in my ability to implement the new curriculum / <i>Je suis parfaitement confiant dans ma capacité d'implémenter du nouveau curriculum.</i>					
4. The new science curriculum is more learner centered than the old one / <i>Le nouveau curriculum de science est plus centré sur l'apprenant que l'ancien</i>					
5. The teaching conditions in my school are conducive for implementing inquiry based science teaching / <i>Les conditions d'enseignement dans mon école sont favorables pour un enseignement de science par investigation</i>					
6. The new science curriculum is easier to implement / <i>Le nouveau curriculum de science est plus simple à implémenter</i>					
7. The physical resources in my school enable me to implement the new curriculum effectively / <i>Les ressources matérielles dans mon école me permettent d'implémenter le nouveau curriculum plus efficacement</i>					
8. Implementing the new curriculum requires me to do more preparation and work than I did before/ <i>Implémenter le nouveau curriculum m'exige plus de travail et de préparation qu'avant.</i>					
9. I am satisfied that I am doing a good job at teaching the new curriculum / <i>Je suis satisfait que je fais du bon travail en enseignant le nouveau curriculum.</i>					

SECTION 3: UNDERSTANDING AND PREPARATION TOWARDS INQUIRY COMPREHENSION ET PREPARATION POUR L'INVESTIGATION

3.1. Provide a short description of what you understand by inquiry based science teaching / *Donnez une brève description de ce que vous entendez par l'enseignement de science par investigation?*

.....

.....

.....

3.2. Rank from the most important (1st) to the least important (6th) role played by each of the following ways in professionally preparing you for teaching science through inquiry?
Rangez du plus important (1^{er}) au moins important (6^e) rôle joué par chacune des voies dans votre préparation pour enseigner la science par investigation?

Ways by which I feel I was prepared/ <i>Voies par lesquelles je me sens avoir été préparé</i>	Rank/ Rang
1. The pre-service academic training / <i>La formation initiale académique</i>	
2. The in-service programs attended / <i>Les programmes en cours d'emploi fréquentés</i>	
3. The advice from the Head or Deputy Head of School / <i>Les conseils du Directeur ou du Préfet des études</i>	
4. My own day to day experience/ <i>Mon expérience personnelle quotidienne</i>	
5. Discussion with my colleagues/ <i>Discussions avec mes collègues</i>	
6. Other (specify)..... <i>Autre (spécifier)</i>	

3.3. Who most helps you when making use of inquiry in your teaching?
Qui vous aide le plus quand vous faites usage d'investigation dans vos enseignements ?

Rank in order of importance (eg. 1st, 2nd, 3rd, ...) / *Ranger selon l'ordre d'importance (ex. 1^{er}, 2^{ème}, 3^{ème},)*

People helping / <i>Personnes qui m'aident</i>	Rank / Rang
1. The Head of School / <i>Le Directeur de l'école</i>	
2. The Deputy Head of School / <i>Le préfet des études</i>	
3. My colleagues / <i>Mes collègues</i>	
4. My own research/ <i>Recherche personnelle</i>	
5. Others (Specify):1).....	
2)	
<i>Autres (spécifier): 1).....</i>	
2)	

3.4. How would you rate whether the following areas have improved since you started using inquiry in your lessons?

Comment jugez-vous que les aspects suivants se seraient améliorés depuis que vous avez commencé à faire usage d'investigation dans vos leçons ?

Give a rough estimate from 1 to 5 where 5 = much improved and 1 = least improved

Donnez une note globale de 1 à 5 où 5 = s'est beaucoup amélioré et 1 = s'est moins amélioré.

Areas / Aspects	5 Much improved	4	3	2	1 Least improved
1. The learners achievement on tests/ <i>La performance des élèves</i>					
2. The learners' attitudes towards science/ <i>Attitudes des élèves envers la science</i>					
3. The classroom discipline/ <i>Discipline en classe</i>					
4. Learners' collaboration with each other/ <i>Collaboration entre les élèves</i>					
5. Your classroom management skills/ <i>Votre habilité de gestion de la classe</i>					
6. Learners' participation in classroom activities/ <i>Participation des élèves dans les activités en classe</i>					
7. The amount of time learners spend learning science at home					
8. Other area (specify it) <i>Autre aspect (spécifiez-le) .</i>					

3.5. Since you started implementing this new curriculum, have you attended any in-service training?

Depuis que vous avez commencé à implémenter ce nouveau curriculum, avez-vous reçu une quelconque formation en cours d'emploi?

Yes / *Oui*

No / *Non*

3.6. If yes, what was the focus? *Si oui, sur quoi portait-elle?*

.....
.....

3.7. For the one you attended, in which area did you most benefit with regard to your science teaching?

Pour celui que vous avez reçu, dans quels domaines avez-vous le plus bénéficié en rapport avec votre enseignement de science?

.....
.....
.....
.....

3.8. If you were given a chance to attend any kind of in-service programme/ training, what areas would you like most to focus on so that you can improve your science teaching? (*Put them in order of importance*)

Si une chance de recevoir une formation en cours d'emploi vous était accordée, dans quels domaines voudriez-vous que soit mis l'accent afin d'améliorer votre enseignement de science? (Placez-les dans l'ordre d'importance)

- 1)
- 2)
- 3)
- 4)

SECTION 4: INQUIRY BASED SCIENCE TEACHING ACTIVITIES / ACTIVITES EN RAPPORT AVEC L'ENSEIGNEMENT DE SCIENCE PAR INVESTIGATION

4.1. How often do you use the following ten teaching and learning activities in your science lessons?
Comment fréquemment utilisez-vous les méthodes d'enseignement et apprentissage suivantes dans vos leçons de science?

Rank the ten teaching activities in order of frequency of use where 1 indicates that you use this the most and 10 indicates you use this activity the least of all the activities.

Donner un rang de 1 à 10 où 1 signifie la plus fréquemment utilisée et 10 la moins fréquemment utilisée.

Teaching and learning methods used in my lessons / <i>Méthodes d'enseignement et apprentissage utilisées dans mes leçons</i>	Rank / <i>Rang</i>
1. Direct teaching: Chalk and talk, lecture / <i>Enseignement direct: exposé magistral</i>	
2. Teacher demonstration: Show learners some real practical phenomenon, manipulate a device, .../ <i>Démonstration par l'enseignant: Montrer en pratique certains phénomènes réels aux élèves</i>	
3. Copy work: Learners copy information from the board (notes, graphs, drawings,)/ <i>Prise de notes: Les élèves prennent note au tableau (notes, graphiques, schémas,.....)</i>	
4. Exercises: Learners work on exercises or problems given to them in a worksheet, textbook or on the board/ <i>Exercices: Les élèves font des exercices ou des problèmes qui leur sont donnés soit sur un papier, dans le livre ou au tableau.</i>	
5. Carrying out a practical work in laboratory setting: Learners following instructions and do practical work and report/ <i>Conduire une activité pratique au laboratoire: Les élèves suivent les instructions, font l'activité pratique et font le rapport</i>	
6. Giving over home works and tests / <i>Donner des devoirs à domicile et des interrogations</i>	
7. Carrying out investigation: Learners work independently or in groups on their own experiment or project and report/ <i>Mener une investigation: Les élèves travaillent individuellement ou en groupes sur leur propre expérience ou projet et font le rapport</i>	
8 Group discussion: Learners work in groups discussing some science topic or concepts and do presentation/ <i>Discussion en groupes: Les élèves travaillent en groupes en discutant sur certains sujets ou concepts et font l'exposé</i>	
9. Project: Learners work individually or in groups on their own projects over a number of lessons (days or weeks)/ <i>Projet: Les élèves travaillent individuellement ou en groupes sur leur propres projets s'étendant sur un certain nombre de leçons (jours ou semaines)</i>	
10. Fieldtrips: Taking learners outside the classroom for a visit of for example a factory, a workshop, a local farm, a hydropower central, <i>Excursions: Amener les élèves hors de la classe pour une visite par exemple d'une usine, d'un atelier, d'une ferme locale, d'une centrale hydroélectrique,</i>	

4.2. How often do the following take place in your science lessons?

A quelle fréquence les faits suivants prennent-ils place dans vos leçons de science ?

Facts / Faits	Always 5 <i>Toujours</i>	Frequently 4 <i>Fréquemment</i>	Sometimes 3 <i>Quelquefois</i>	Rarely 4 <i>Rarement</i>	Never 1 <i>Jamais</i>
1. I decide on the topic to be studied/ <i>Je décide seul du sujet à étudier</i>					
2. I let students decide on the topic to be studied/ <i>Je laisse les élèves décider du sujet à étudier</i>					
3. I ask learners to search for additional information on topics we discussed in the classroom/ <i>Je demande aux élèves de chercher d'information supplémentaires sur les sujets discutés en classe</i>					
4. In my lessons I am focused on teaching topics and questions that will appear in the end of O'level national examination / Dans mes leçons je focalise seulement sur le l'examen national de fin du TC					
5. I am focused on completing all assigned topics in the syllabus and do not stray to topics outside the curriculum/ <i>Je vise seulement à terminer les chapitres prévus au programme</i>					
6. I set the lesson pace to the slowest learners / <i>J'avance au rythme d'élèves les plus lents</i>					
7. I strive to make sure all students equally participate / <i>Je m'efforce de m'assurer que tous les élèves participant de la même façon</i>					
9. I also learn from my learners when using inquiry / <i>J'apprend aussi de mes élèves quand je fais usage d'investigation</i>					

SECTION 5: FACTORS INFLUENCING YOUR CURRENT PRACTICES

FACTEURS INFLUENCANT VOS PRATIQUES ACTUELLES

5.1. To what extent do you agree or disagree with the following statements about the factors that impede your current implementation of inquiry-based science teaching?

Indiquer à quel degré vous êtes d'accord ou non avec les assertions suivantes en rapport avec les facteurs qui gênent votre enseignement de science par investigation ?

Statements / Assertions	Strongly agree/ <i>Tout à fait d'accord</i>	Agree/ <i>D'accord</i>	No opinion/ <i>Sans opinion</i>	Disagree/ <i>Désaccord</i>	Strongly disagree/ <i>Tout à fait désaccord</i>
1. Planning and teaching Inquiry lessons are more time consuming / <i>Une leçon par investigation prend trop de temps</i>					
2. My classes are too large to do inquiry / <i>Mes classes sont trop larges</i>					
3. I don't have enough experience to do inquiry teaching/ <i>Je n'ai pas assez d'expérience</i>					
4. Students do not enjoy inquiry / <i>Les élèves n'aiment pas l'investigation</i>					
5. Inquiry doesn't help students to pass their exams / <i>L'investigation n'aide pas les élèves à passer leurs examens</i>					
6. Using the inquiry approach prepares learners for answering national examination questions/ <i>L'Usage de l'enseignement par investigation prépare les élèves à répondre aux questions d'examen national</i>					
7. I feel confident in applying this teaching approach / <i>Je me sens confiant à appliquer cette approche</i>					
8. Now that I am doing inquiry I enjoy my job more than before / <i>Maintenant que je fais usage d'investigation, je me plais de mon travail plus qu'avant.</i>					
9. I don't feel the need of changing the way I have been teaching over the years/ <i>Je ne sens pas la nécessité de changer ma façon d'enseigner</i>					
10. The way I was taught at university and college prepared me to use this approach / <i>La façon dont j'étais enseigné à l'université m'a formé pour l'usage de cette approche</i>					

SECTION 6: IMPROVEMENT OF SCIENCE TEACHING THROUGH INQUIRY

AMELIORATION DE L'ENSEIGNEMENT PAR INVESTIGATION

6.1. In order to make inquiry teaching more effective and achieve the aims of the TC science curriculum I would agree with the following suggestions

En vue de faire de l'enseignement de science par investigation plus efficace et atteindre les objectifs du curriculum, je serais d'accord avec les assertions suivantes

Statements/ Assertions	Strongly agree/ <i>Tout à fait d'accord</i>	Agree/ <i>D'accord</i>	No opinion/ <i>Sans opinion</i>	Disagree/ <i>Désaccord</i>	Strongly disagree/ <i>Tout à fait désaccord</i>
1. Teacher training institutions should change the way science teachers are prepared / <i>Les institutions qui forment les enseignants devraient changer la façon dont les enseignants de science sont préparés</i>					
2. Schools should be automatically supplied with required science teaching resources / <i>Les écoles devraient avoir le matériel didactique de science requis</i>					
3. Teachers using inquiry approach should be given an extra bonus/ <i>Les enseignants qui utilisent l'investigation devraient avoir une prime supplémentaire</i>					
4. Science teachers' workload should be reduced to allow for practical preparation / <i>La charge horaire des enseignants de science devrait être revue à la baisse pour permettre la préparation des pratiques</i>					
5. Science teachers should be evaluated to see if they have skills to do inquiry/ <i>Les enseignants de science devraient être testés s'ils ont les aptitudes de faire l'investigation</i>					
6. If teachers do not have these skills they should be compelled to attend courses in holidays/ <i>Si les enseignants n'ont pas ces aptitudes ils devraient obligatoirement suivre les cours pendant les vacances</i>					
7. If a school does not have resources it may not be compelled to follow an inquiry curriculum/ <i>Si une école n'a pas de matériel requis, il n'est pas tenu de suivre le curriculum d'investigation</i>					

6.2. Any other comment (*Put whatever comments you find useful with regard to this topic*)

Autre commentaire (Mettez n'importe quel autre commentaire que vous estimez utile en rapport avec ce sujet)

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Time table / *Horaire*

Time (from– to) <i>Temps</i> (de – à)	Monday <i>Lundi</i>	Tuesday <i>Mardi</i>	Wednesday <i>Mercredi</i>	Thursday <i>Jeudi</i>	Friday <i>Vendredi</i>	Saturday <i>Samedi</i>

Thank you very much for your time/ *Merci beaucoup pour votre temps*

Would you please provide your telephone number if you would allow me to contact you for further details? Telephone Number:

Pourriez-vous s'il vous plait donner votre numéro de téléphone au cas où vous accepteriez d'être contacté pour plus de détails? Numéro de téléphone:

APPENDIX B: INTERVIEW SCHEDULE

QUESTIONS
<p>1. a) Can you tell me more about your teaching experience as science teacher? (number of years teaching science, qualification, subjects taught,)</p> <p>b) Describe your daily teaching of science? In other words, how do you go about your teaching of science i.e what do you do and what do the learners do?</p>
<p>2. Teaching science may have several purposes such as teaching the nature of science, the process of science, learning content and facts, understanding of concepts, students learning to inquire, getting good marks on tests etc. In your daily teaching what is your main goal?</p>
<p>3. How do you know when you have been successful in achieving your aims?</p>
<p>4. What methods of teaching seem to work best for you and why?</p>
<p>5. The new science curriculum being implemented has introduced inquiry teaching and learning approach:</p> <p>a) What is actually your understanding of inquiry-based science teaching?</p> <p>b) Considering the prevailing conditions in your school, how do you go about implementing this new science curriculum?</p> <p>c) Describe the main steps or activities you go through when using inquiry strategies in your classroom.</p>
<p>6. The introduction of inquiry in the new curriculum is seen as a paradigm shift from the teacher-centred to the learner-centred teaching and learning approach.</p> <p>a) Was there any need of change?</p> <p>b) Are you in favour of this change?</p> <p>c) What are other features of the new science curriculum compared to the old one?</p>
<p>7. a) How often do you use inquiry in your daily teaching? Why?</p> <p>b) If you can get the same results on tests when you use inquiry teaching approach or direct teaching, which one would you use? Why?</p>
<p>8. a) In your daily teaching, what areas of teaching and learning have improved since you started using inquiry in your science teaching?</p> <p>b) When you are not using the approach, what are the major reasons that prevent you from using the approach?</p>
<p>9. We are not sure what the benefits of inquiry are. Some researchers say that inquiry results in more learners' understanding; others say that it does not result in better achievement in tests while others say</p>

that it teaches about science. What is your opinion and why?

10. When I asked teachers their feeling about the role played by each of the different ways of preparing them for teaching science, the PRESET (academic) was put in first position. But on the other hand, when they were asked what should be done to make inquiry teaching more effective, they mainly reported that teacher training institutions should change the way they prepare science teachers which is a bit contradictory.

a) What is your view about science teachers' preparation?

b) Is there any strategy you think can be adopted to get well trained teachers able to implement the new science curriculum?

11. In your view, is there any kind of support you lack or you would like to be provided with for better implementation of inquiry based science teaching approach? How could this be done?

12. Do you have any other comment about science teaching and learning at O' level in Rwanda?

APPENDIX C: ETHICAL CLEARANCE

RESEARCH OFFICE (GOVAN MBEKI CENTRE)
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29 NOVEMBER 2010



Mr. LR Mugabo (204520950)
School of Sciences, Mathematics, Technology and Education

Dear Mr. Mugabo

PROTOCOL REFERENCE NUMBER: HSS/1011/010D
PROJECT TITLE: The introduction of Inquiry Science teaching in Rwandan lower secondary school:
Teachers attitudes and perceptions.

EXPEDITED APPROVAL

This letter serves to notify you that your application in connection with the above has now been granted full approval following your response to queries raised by the Humanities and Social Sciences Research Ethics Committee.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach/Methods must be reviewed and approved through an amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years

Best wishes for the successful completion of your research protocol.

Yours faithfully

PROFESSOR STEVEN COLLINGS (CHAIR)
HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE

cc. Supervisor - Prof. P Hobden
cc. Mr. N Memela

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